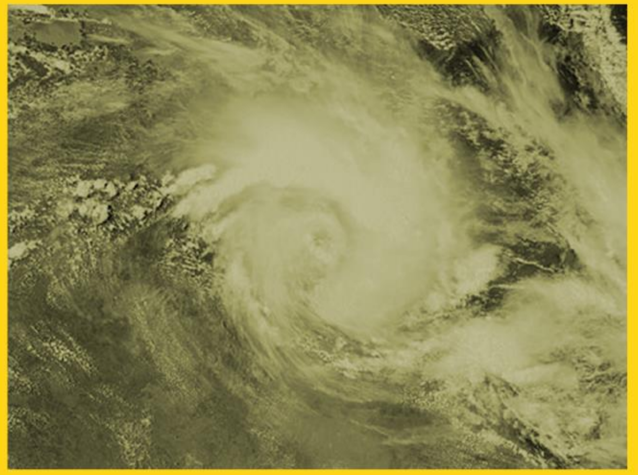

NATURAL HAZARD DECISION SUPPORT SYSTEM

Jeff P. Newman, Holger R. Maier, Hedwig van Delden, Aaron Zecchin, Graeme C. Dandy
School of Civil, Environmental and Mining Engineering, The University of Adelaide, SA

An Australian Government Initiative

TODAY'S PRESENTATION

The problem that the research is addressing

Objectives of the research program

Methodology and deliverables

TODAY'S PRESENTATION

The problem that the research is addressing

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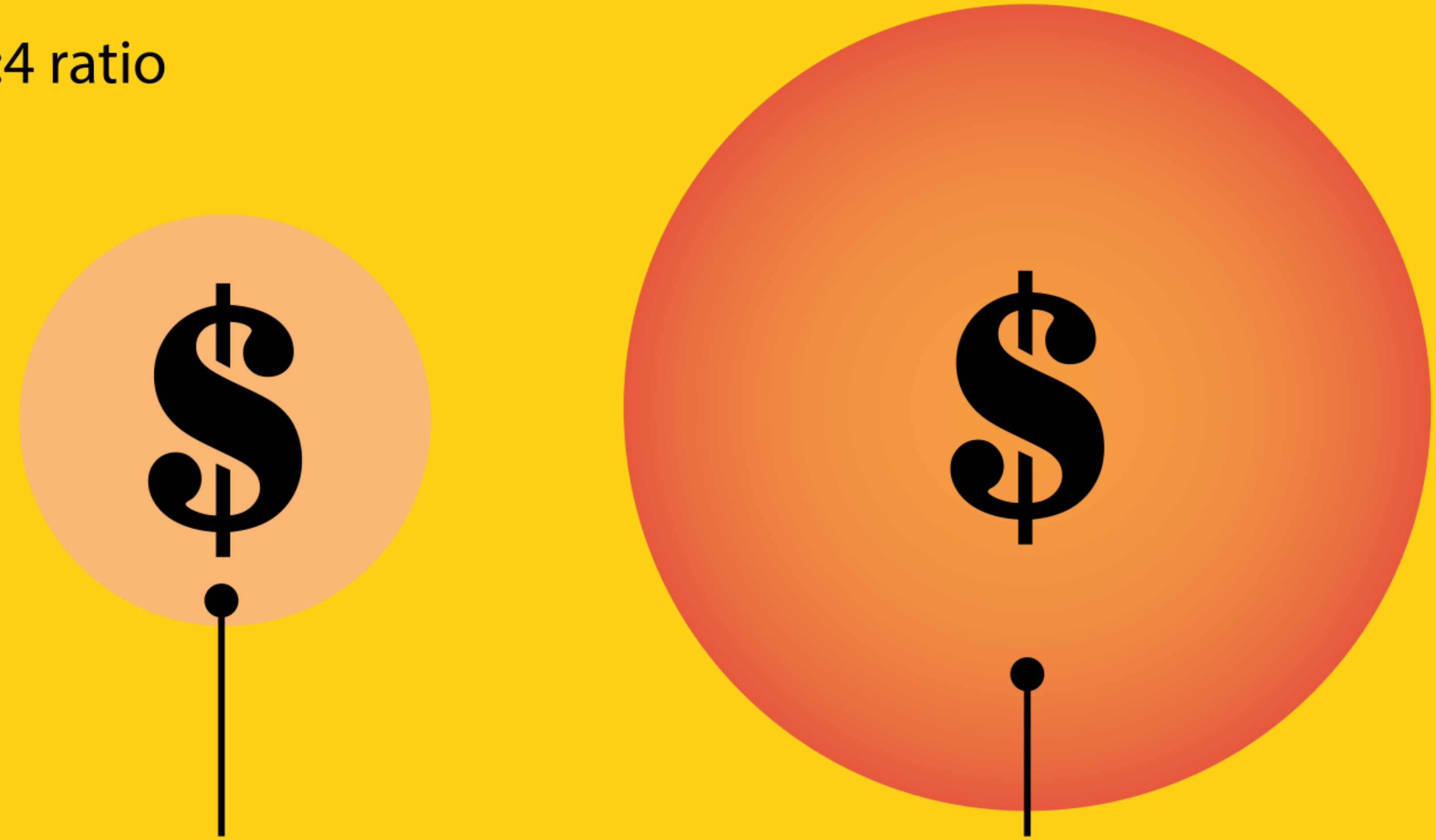
Mitigation Investment Ratio

1:4 ratio

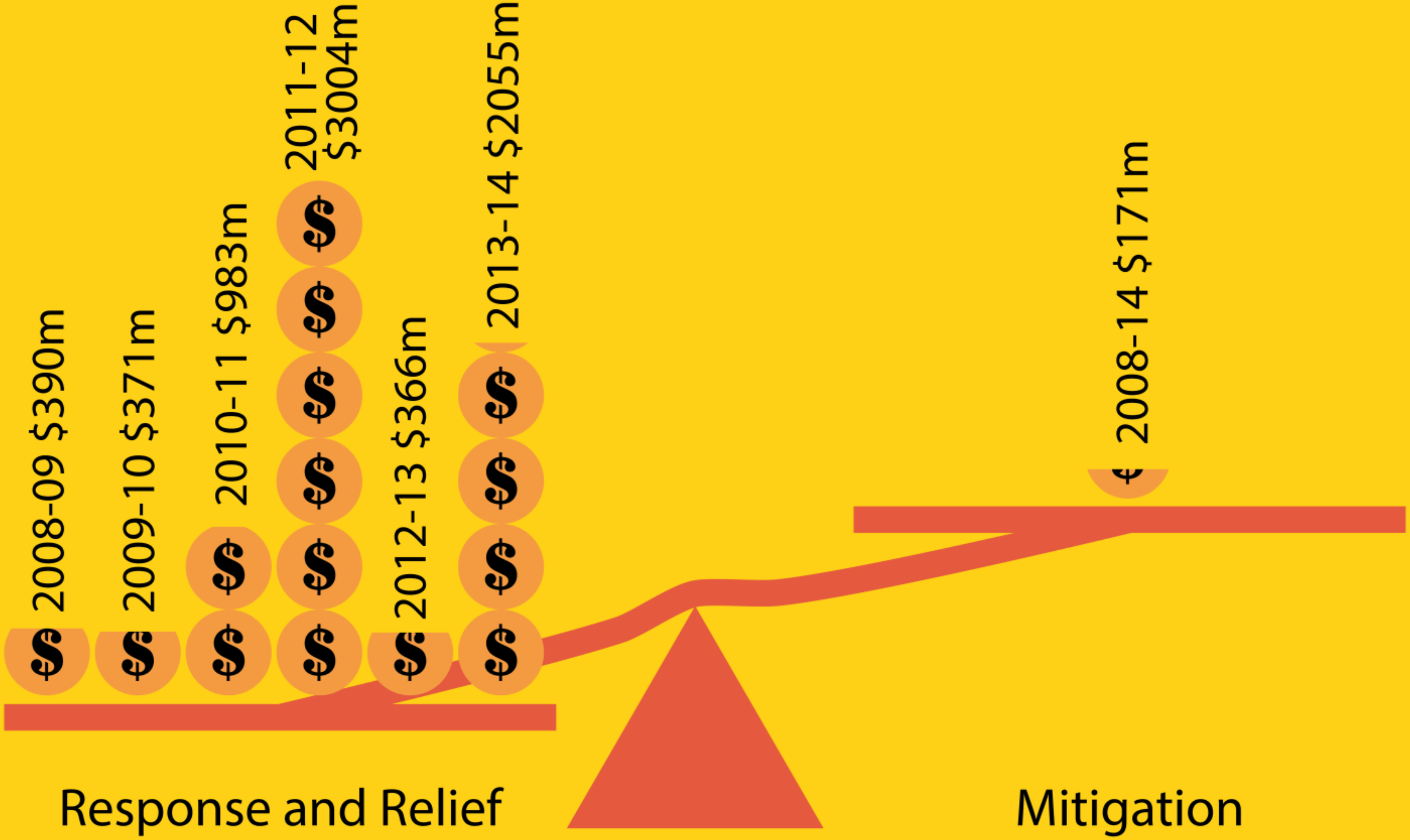


Predisaster
Mitigation spend

Reduces present value
of postdisaster recovery spend
by factor of about 4

bnhcrc.com.au

Mitigation Investment Ratio



NEVERTHELESS, *OBSTACLES* ARE PRESENT WITH REGARD TO MITIGATION PLANNING…

Competing objectives

Risk and uncertainty

Community expectation

Large number of options

Insufficient data / information

Lack of measurable criteria

TODAY'S PRESENTATION

The problem that the research is addressing

Objectives of the research program

Methodology and deliverables

We are developing

A **Decision Support** System for the Assessment of **Policy & Planning Investment Options** For **Optimal** Natural Hazard Mitigation

OBJECTIVES

1) To develop a **systematic and transparent approach** to sifting through, evaluating and ranking disaster and natural hazard mitigation options using analytical processes and tools.

2) To develop user-friendly **prototype software tools** that implement the above approach

3) To **test the software** across three end-user defined case studies.

TODAY'S PRESENTATION

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Multi-hazard Mitigation Options

Sift through large number of mitigation options with optimisation

Spatially explicit, temporal, integrated model

Optimal mitigation portfolios

Multi-hazard Mitigation Options

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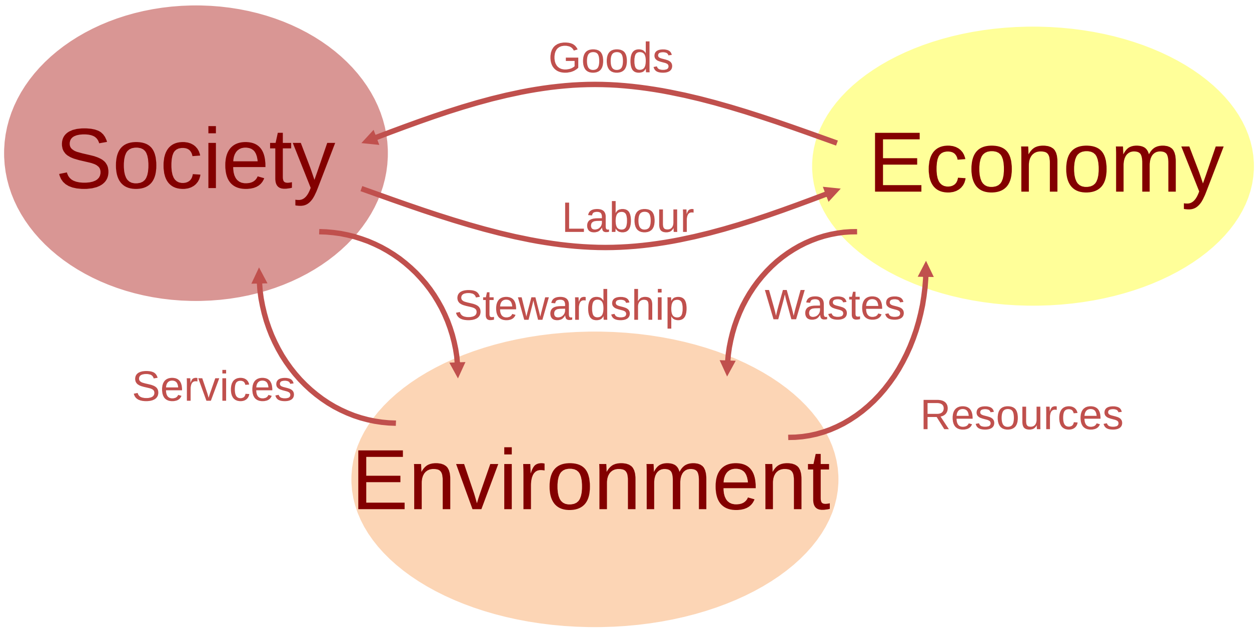


An integrated modelling system is used to evaluate decision criteria for options

Source: Landcare Research 2004

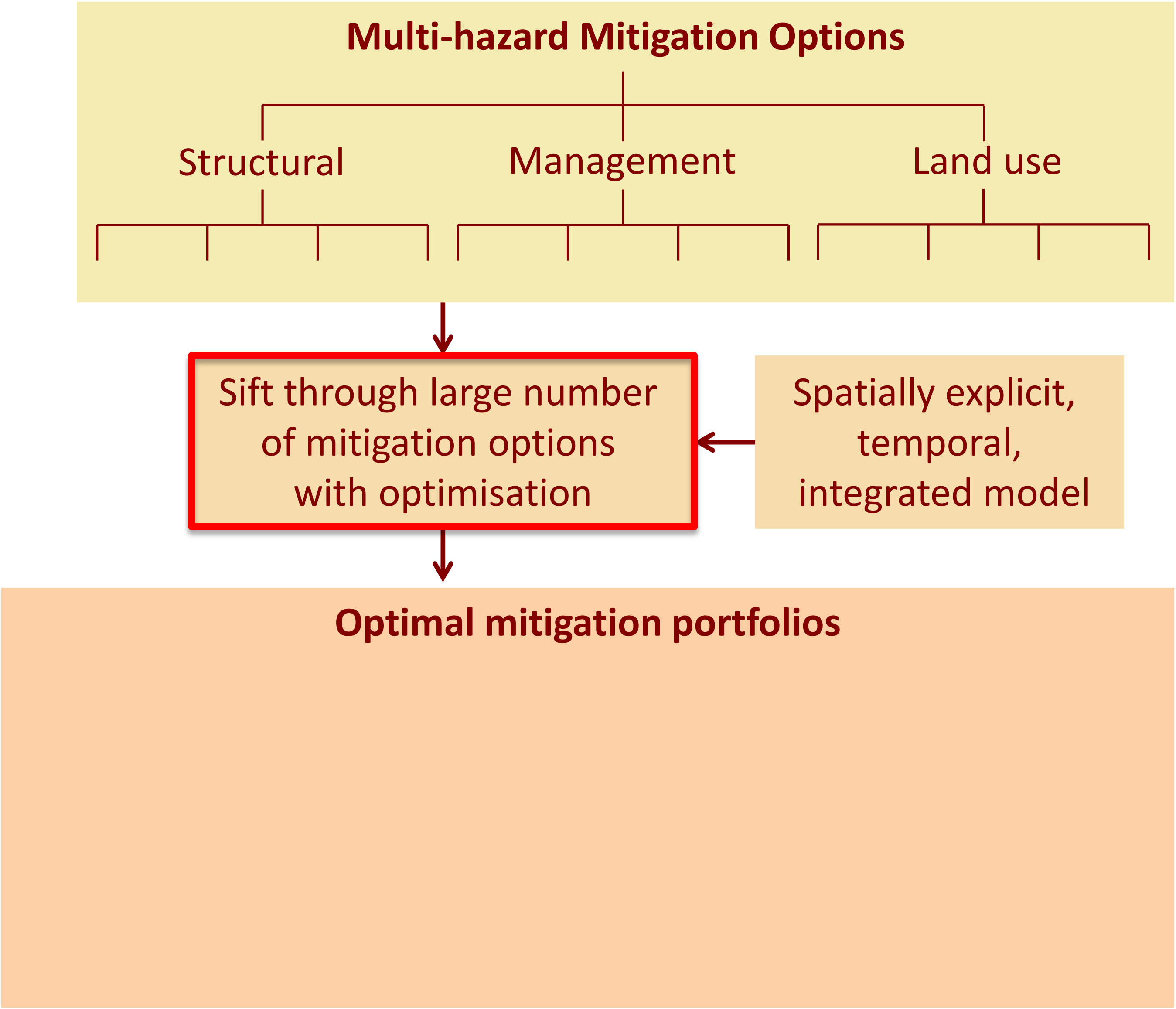
Multi-hazard Mitigation Options

- Structural
- Management
- Land use

Sift through large number of mitigation options with optimisation

Spatially explicit, temporal, integrated model

Optimal mitigation portfolios


Multi-hazard Mitigation Options
Structural
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Optimal mitigation portfolios

Due to the large number of mitigation portfolios evaluating each is computationally intractable

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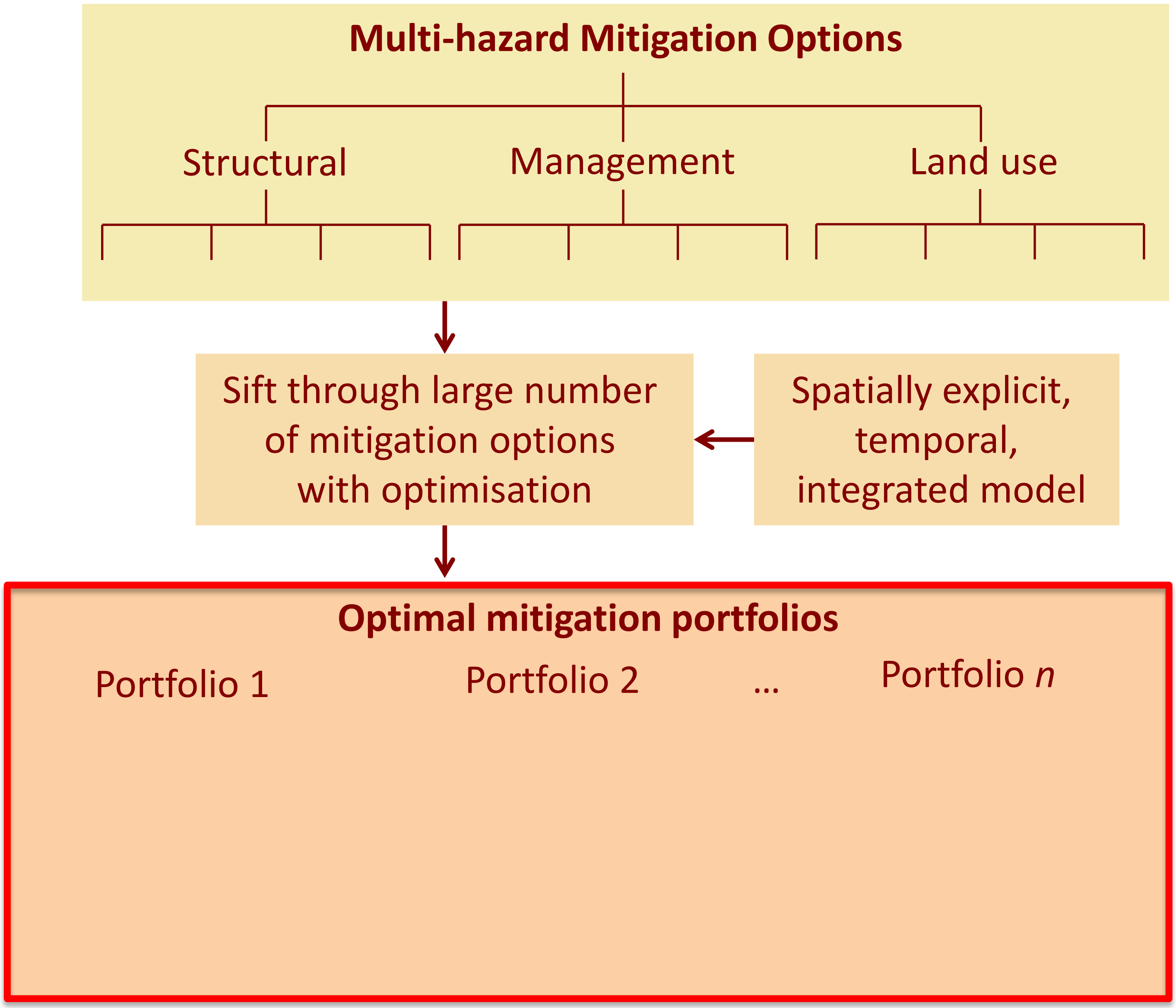
Objectives functions are evaluated using the complex, nonlinear, dynamic integrated modelling system

EVOLUTIONARY ALGORITHMS

1) Use value of **objective function** directly (can link with simulation models)
2) Robust in large decision spaces
3) Search using a **population of decision variable sets** simultaneously
4) Use **probabilistic** rules to understand why some decision variable sets performed better
5) Uses these rules to improve the population of decision variable sets
6) Uses this process, in an iterative fashion, to improve decision variable set over time

Due to the large number of mitigation portfolios evaluating each is computationally intractable

Objectives functions are evaluated using the complex, nonlinear, dynamic integrated modelling system


Multi-hazard Mitigation Options
Structural
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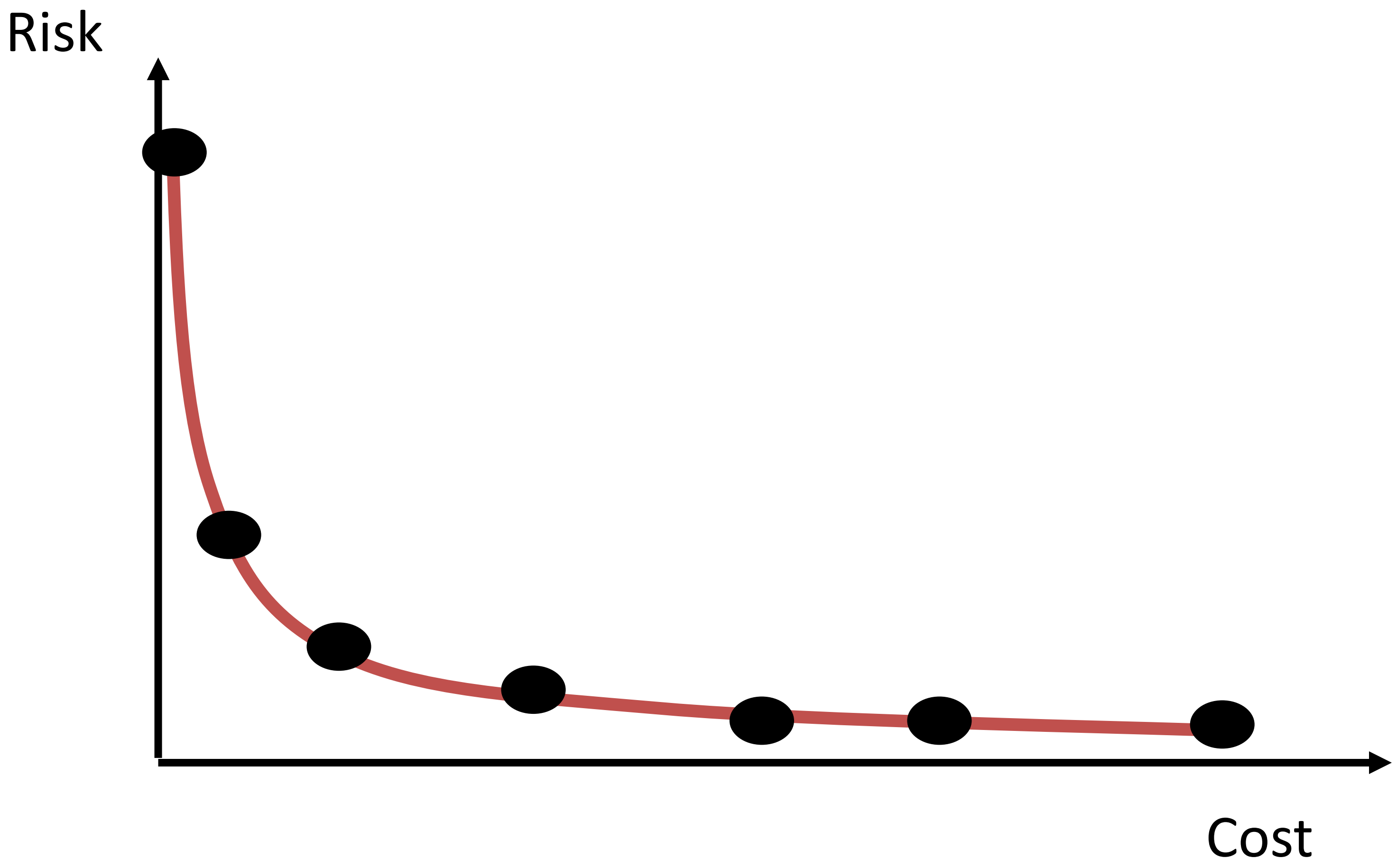
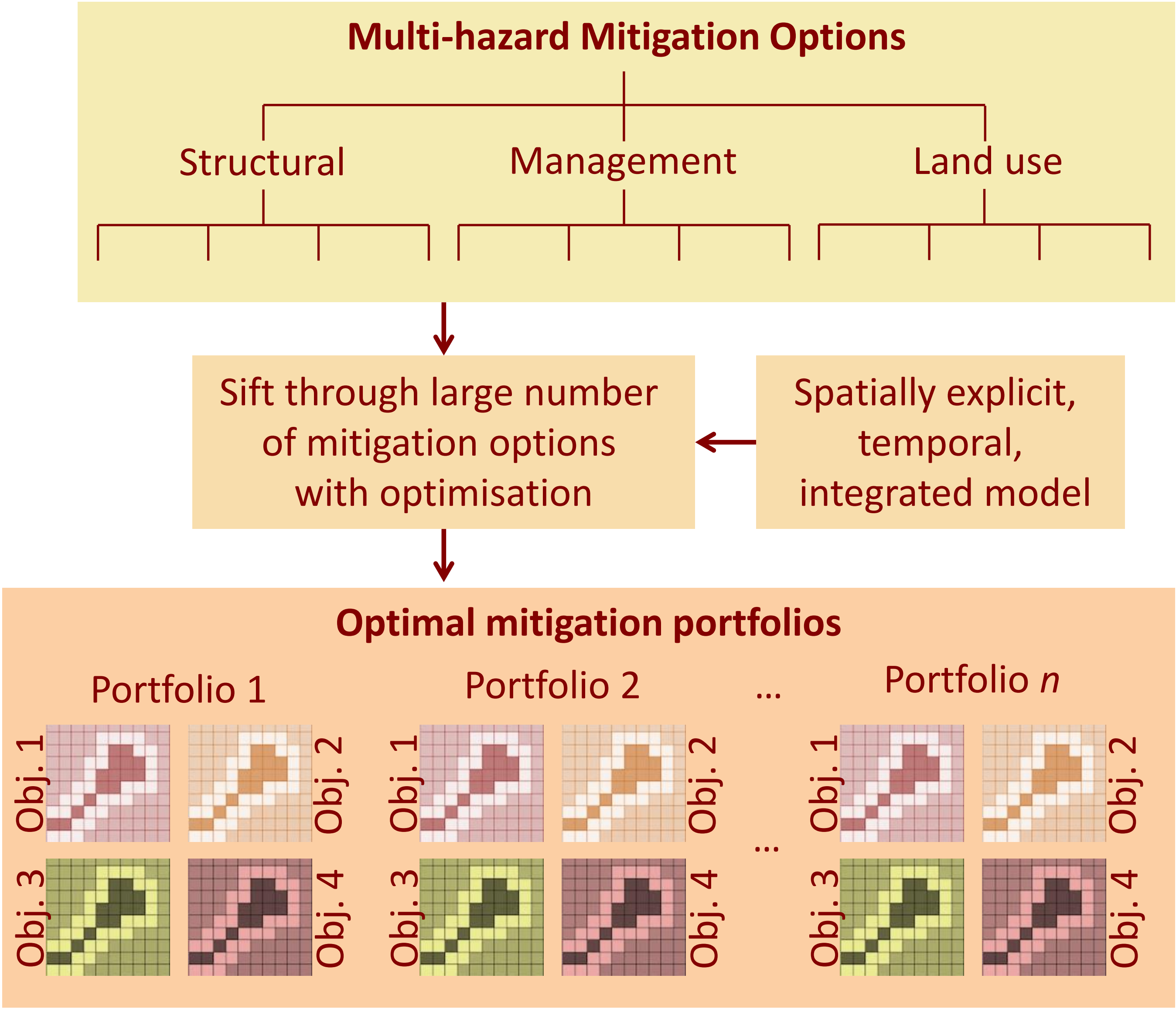
Optimal mitigation portfolios
Portfolio 1
Portfolio 2
…
Portfolio *n*


Risk
Cost


Multi-hazard Mitigation Options
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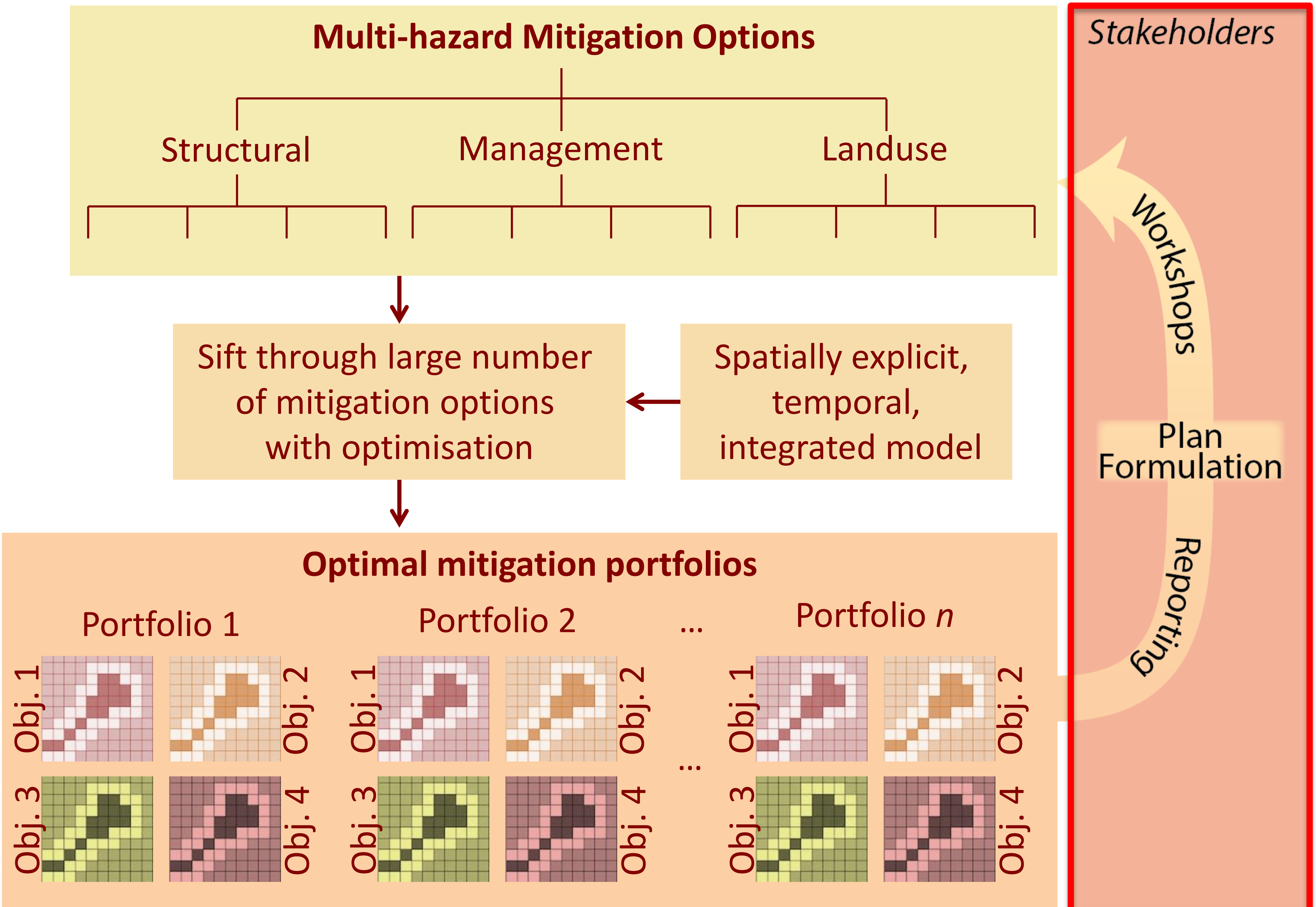
Portfolio 1
Portfolio 2
…
Portfolio n
Obj. 1
Obj. 2
Obj. 3
Obj. 4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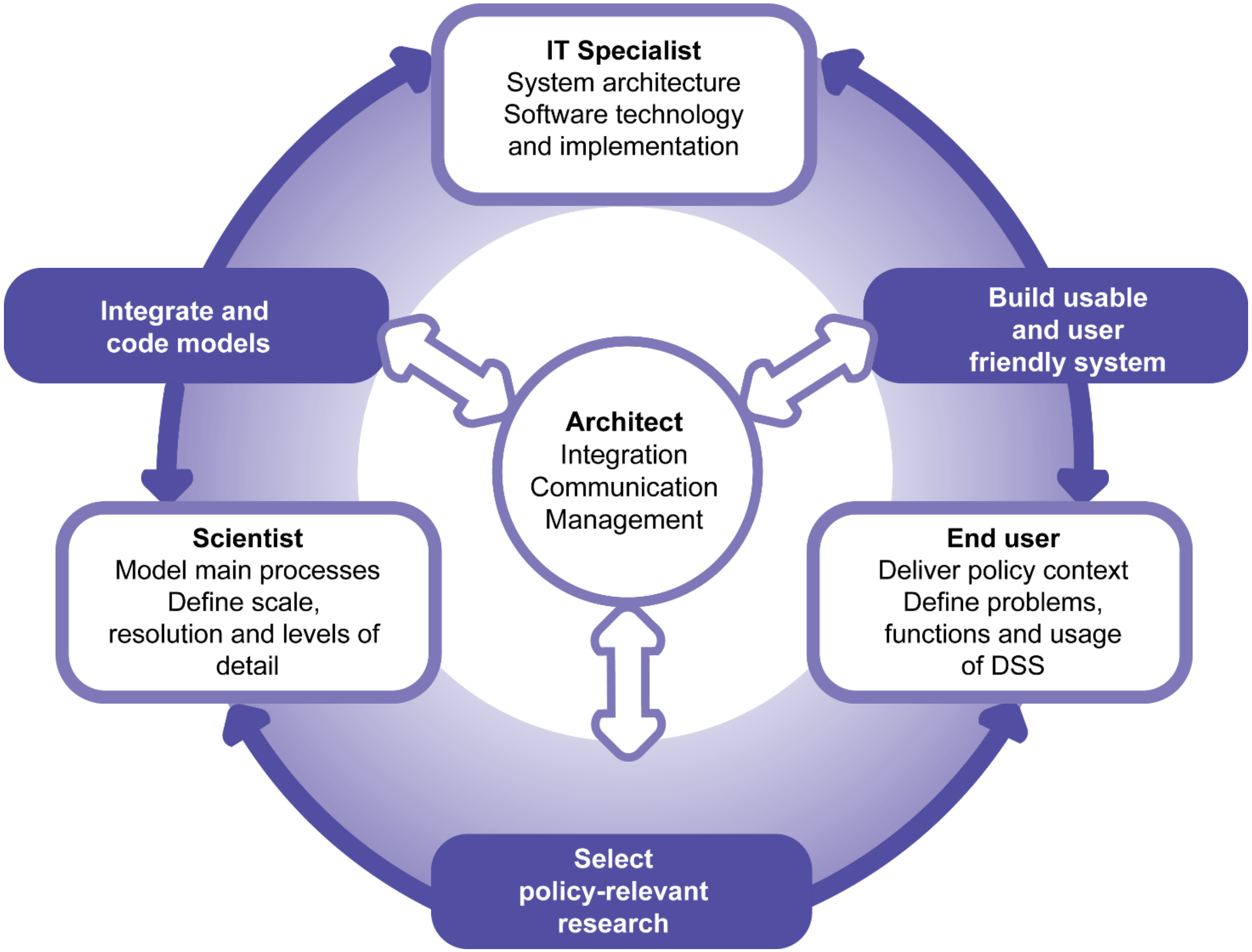
Portfolio 1
Portfolio 2
…
Portfolio n
Obj. 1
Obj. 2
Obj. 3
Obj. 4
Stakeholders
Workshops
Plan Formulation
Reporting

AN ITERATIVE AND INTERACTIVE PROCESS



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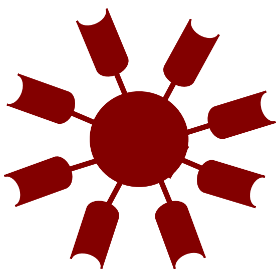
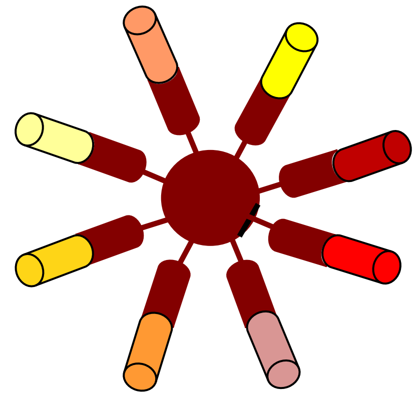
BUILT USING GEONAMICA: A MODULAR WAY OF MODELLING

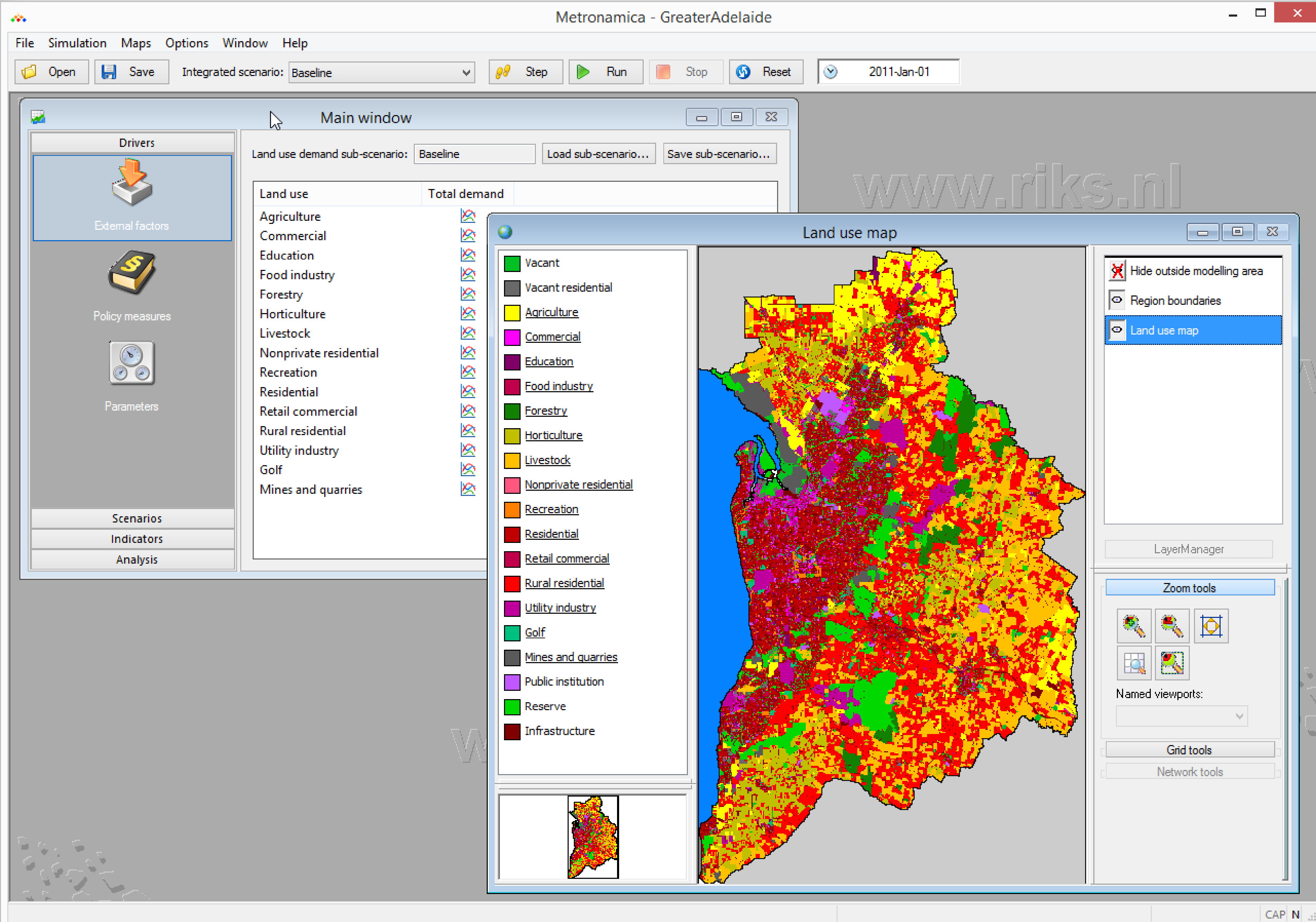


GEONAMICA

- Land use local level
- Earthquake risk model
- Flooding risk model
- Bushfire risk model
- Climate
- Demographics
- Economics
- …



Policy Support System


Metronamica - GreaterAdelaide
File Simulation Maps Options Window Help
Open Save Integrated scenario: Baseline Step Run Stop Reset 2011-Jan-01
Main window
Drivers
External factors
Policy measures
Parameters
Scenarios
Indicators
Analysis
Land use demand sub-scenario: Baseline
Load sub-scenario...
Save sub-scenario...
Land use
Total demand
Agriculture
Commercial
Education
Food industry
Forestry
Horticulture
Livestock
Nonprivate residential
Recreation
Residential
Retail commercial
Rural residential
Utility industry
Golf
Mines and quarries
www.riks.nl
Land use map
Vacant
Vacant residential
Agriculture
Commercial
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Horticulture
Livestock
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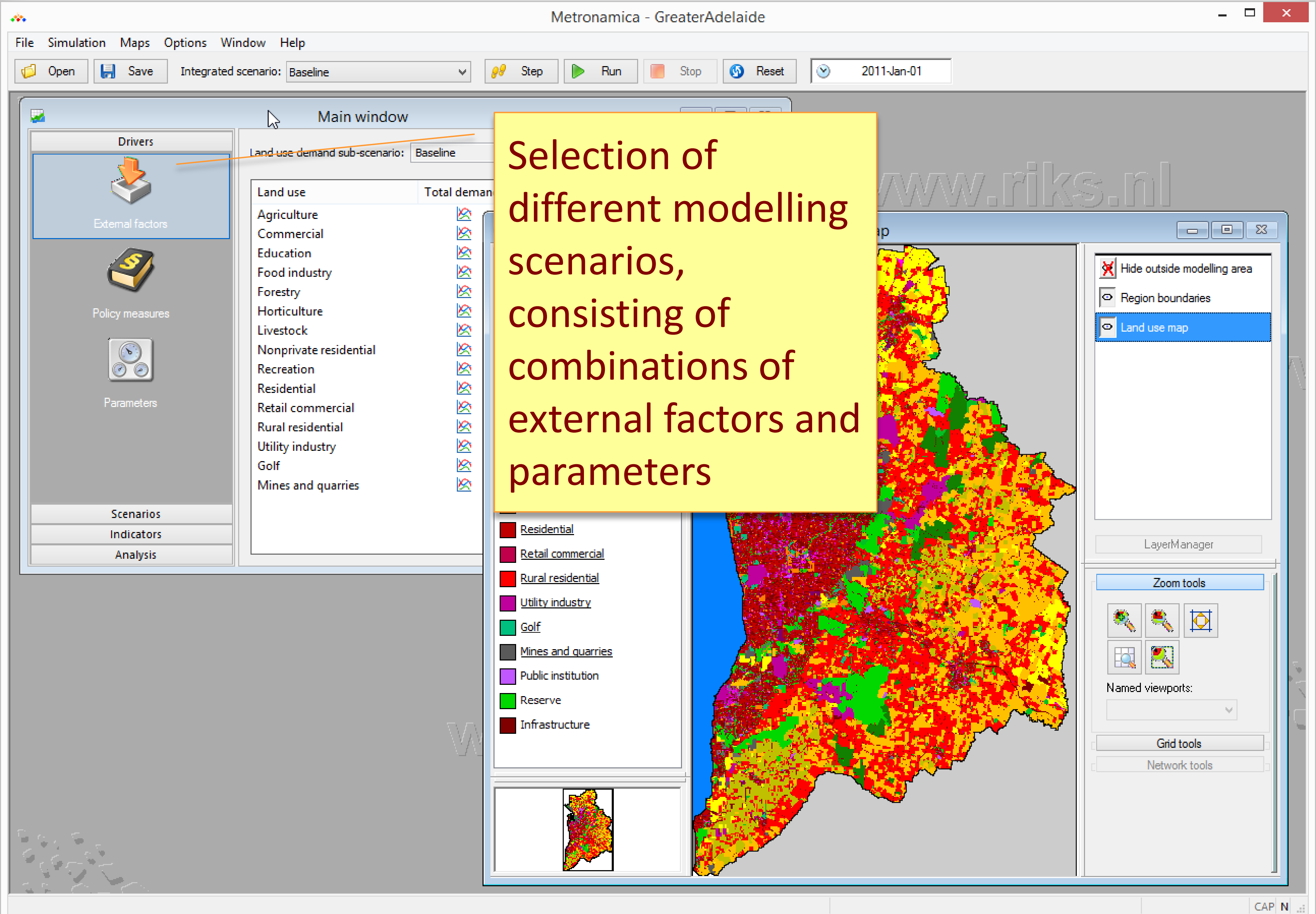
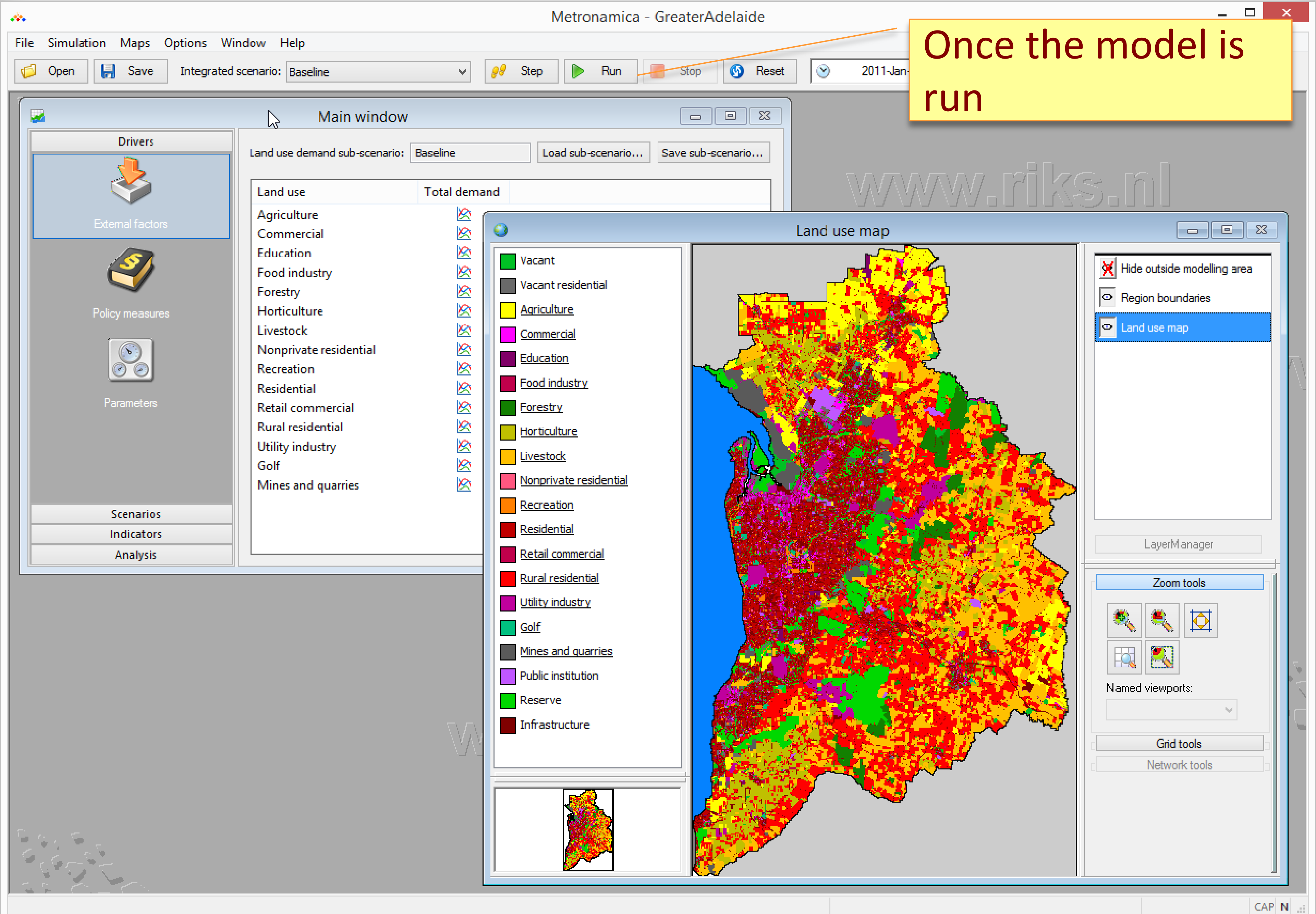
Recreation
Residential
Retail commercial
Rural residential
Utility industry
Golf
Mines and quarries
Public institution
Reserve
Infrastructure
Hide outside modelling area
Region boundaries
Land use map
LayerManager
Zoom tools
Named viewports:
Grid tools
Network tools
CAP N



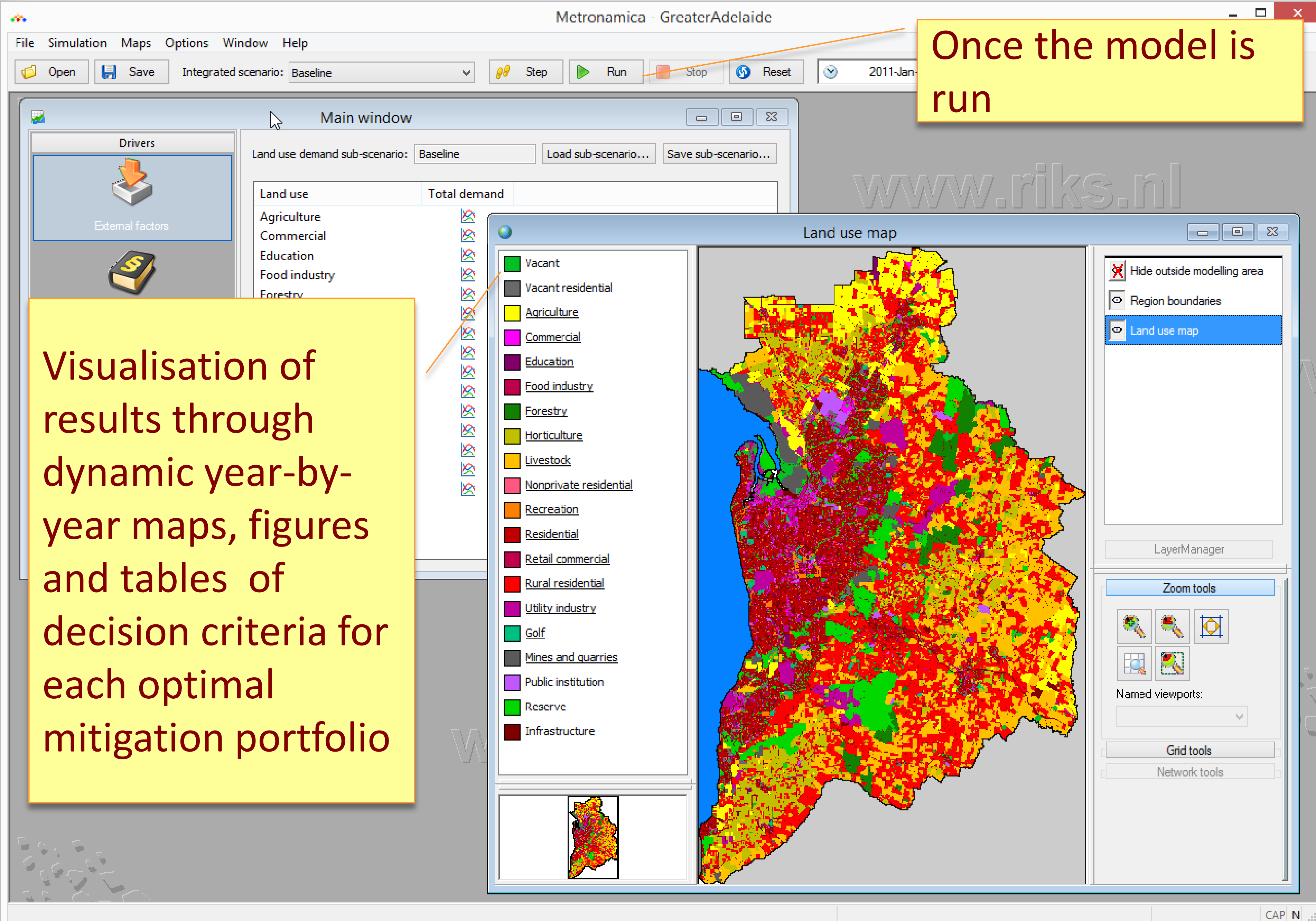
Selection of different modelling scenarios, consisting of combinations of external factors and parameters

Once the model is run



Once the model is run

Visualisation of results through dynamic year-by-year maps, figures and tables of decision criteria for each optimal mitigation portfolio



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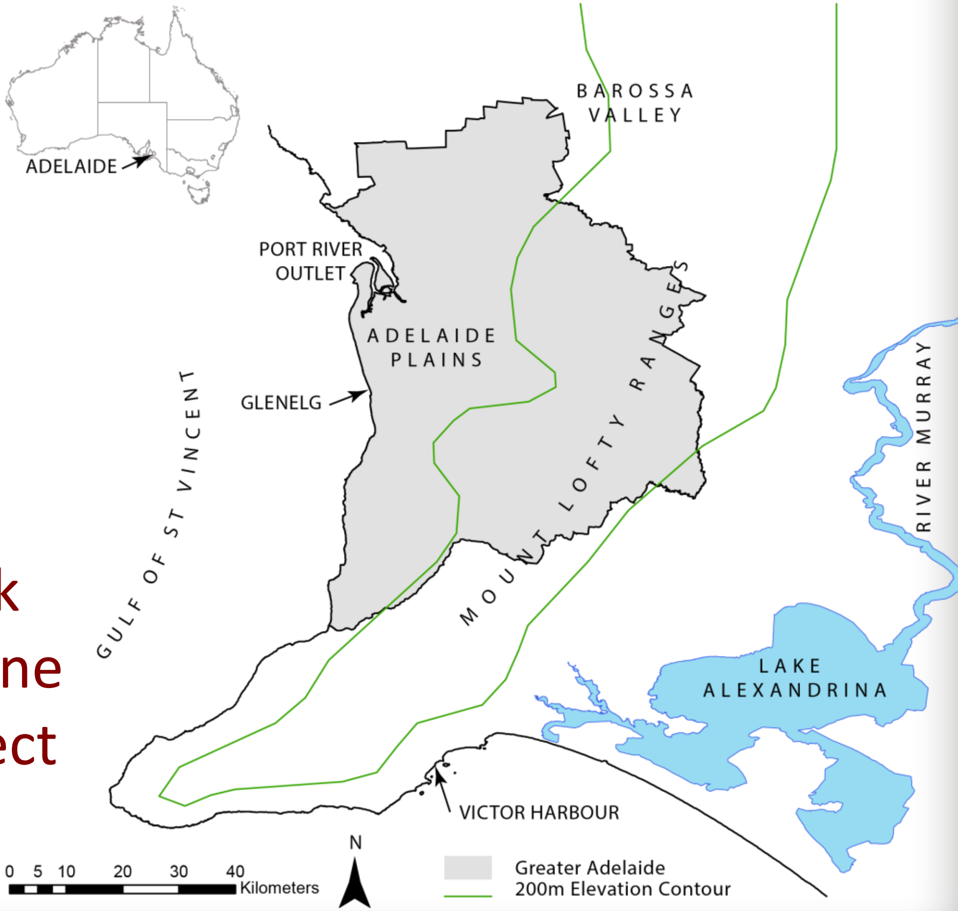
GREATER ADELAIDE CASE STUDY

Work has started on a South Australian case study

- Hazards:
  - Flooding (land and sea),
  - bushfire,
  - earthquake,
  - storms,
  - heatwaves
- Workshop on the 18th of September to obtain feedback on prototype system, and refine models, data and policy/project options.



Two more case studies yet to be decided…

MAJOR OUTCOMES (1)

1) Utilisation of a **systematic** and **transparent** approach to evaluating disaster and natural hazard mitigation options (e.g. infrastructure, land use, policy).

2) The ability to make **more strategic** and **less responsive** decisions in relation to mitigating the impact of disasters and natural hazards as a result of the availability of better information.

MAJOR OUTCOMES (2)

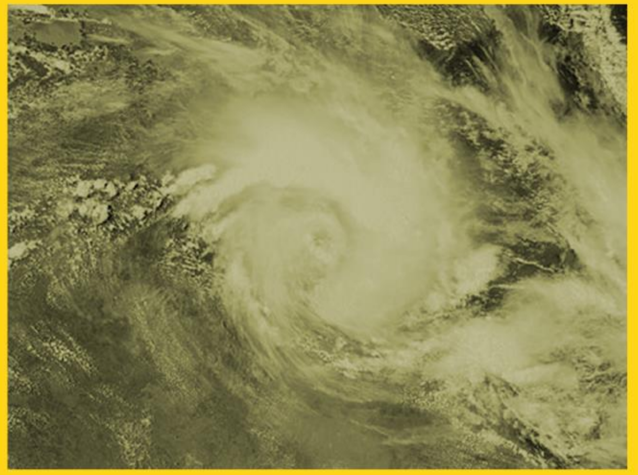
3) The availability of **prototype decision support software tools** for **three** end-user defined **case studies** to enable recommended options to be identified by sifting through and evaluating and ranking a large number of options).

4) A better understanding of the **trade-offs between economic, environmental and/or social objectives** for different mitigation options for three end-user defined case studies.

ADVANTAGES OF OUR APPROACH

1) Focuses on mitigation
2) Integrated approach
3) Considers nonstationarity in landuse and climate
4) Deals with uncertainty in a risk-based approach
5) incorporates optimization in combination with simulation.
6) Uses what we know today, and uses advanced computational techniques to make the most of this





NATURAL HAZARD DECISION SUPPORT SYSTEM

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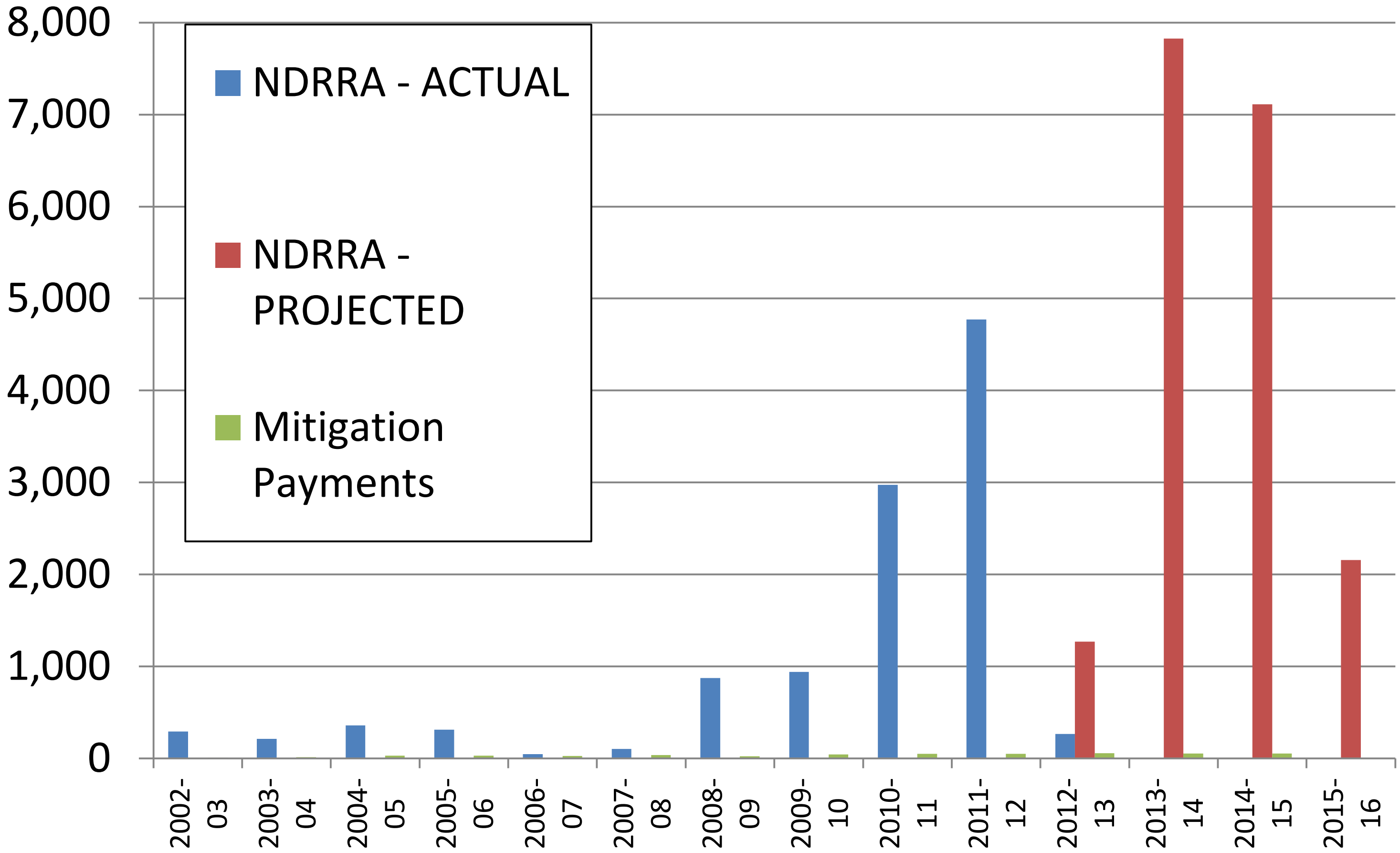
ACKNOWLEDGEMENTS

1) Prof Holger Maier (U of A – Project Leader)
2) A/Prof Hedwig van Delden (U of A / RIKS)
3) Ed Pikusa(SA Fire and Emergency Services Commission)

MITIGATION VS RELIEF SPENDING



Relief/Recovery: $27,364m in 13 years

Mitigation: $480m in 13 years

PROJECT TEAM - RESEARCHERS

1) Prof Holger Maier (U of A – Project Leader)
2) A/Prof Hedwig van Delden (U of A / RIKS)
3) Dr Aaron Zecchin (U of A)
4) Prof Graeme Dandy (U of A)
5) Dr Ariella Helfgott (U of A)
6) Jeff Newman (U of A)

7) Graeme Riddell (U of A – PhD Student)
8) Charles Newland (U of A – PhD Student)

PROJECT TEAM – END-USERS

1) Ed Pikusa(SA Fire and Emergency Services Commission)
2) Alen Slijepcevic (Country Fire Authority, VIC)
3) Samantha Ward (Commonwealth Attorney-General's Department)
4) Sandra Wight (State Fire Management Council, TAS)
5) Stuart Midgley(NSW Rural Fire Service)
6) David Launder(Metropolitan Fire Service, SA)

OVERVIEW OF DSS PROJECT

1) Motivation

2) Conceptual Approach

3) Methodology

4) Milestones

5) Personnel

‘A WICKED PROBLEM’

- Complex, highly interlinked system
- Non-stationary, spatially explicit problem
- Decision maker has no ‘right to be wrong’
- Too many policy/project options to consider
- No one, perfect solution

Competing objectives

Risk and uncertainty

Community expectation

Large number of options

Insufficient data / information

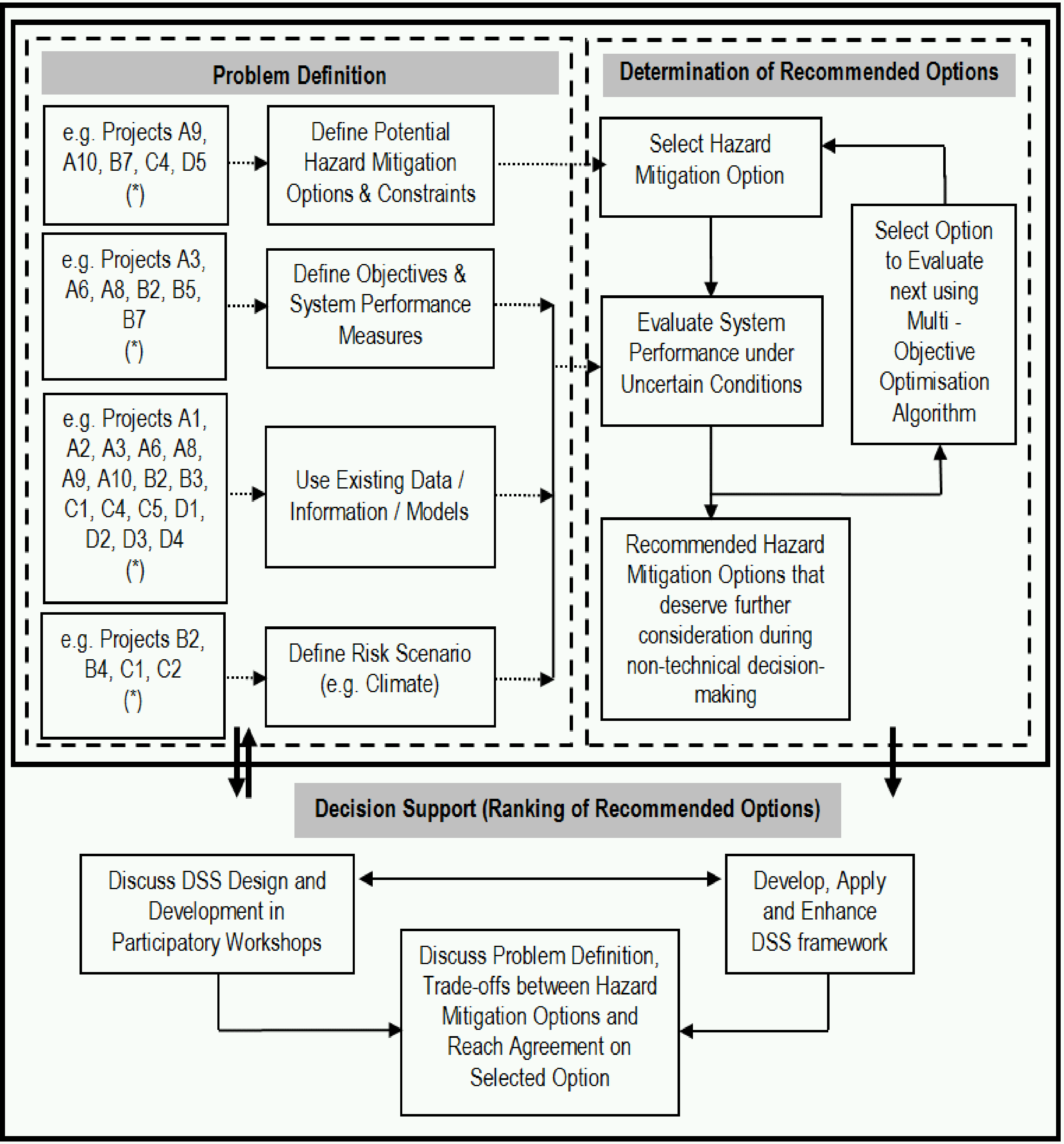
Lack of measurable criteria

WE ALL KNOW MITIGATION IS COST EFFECTIVE …

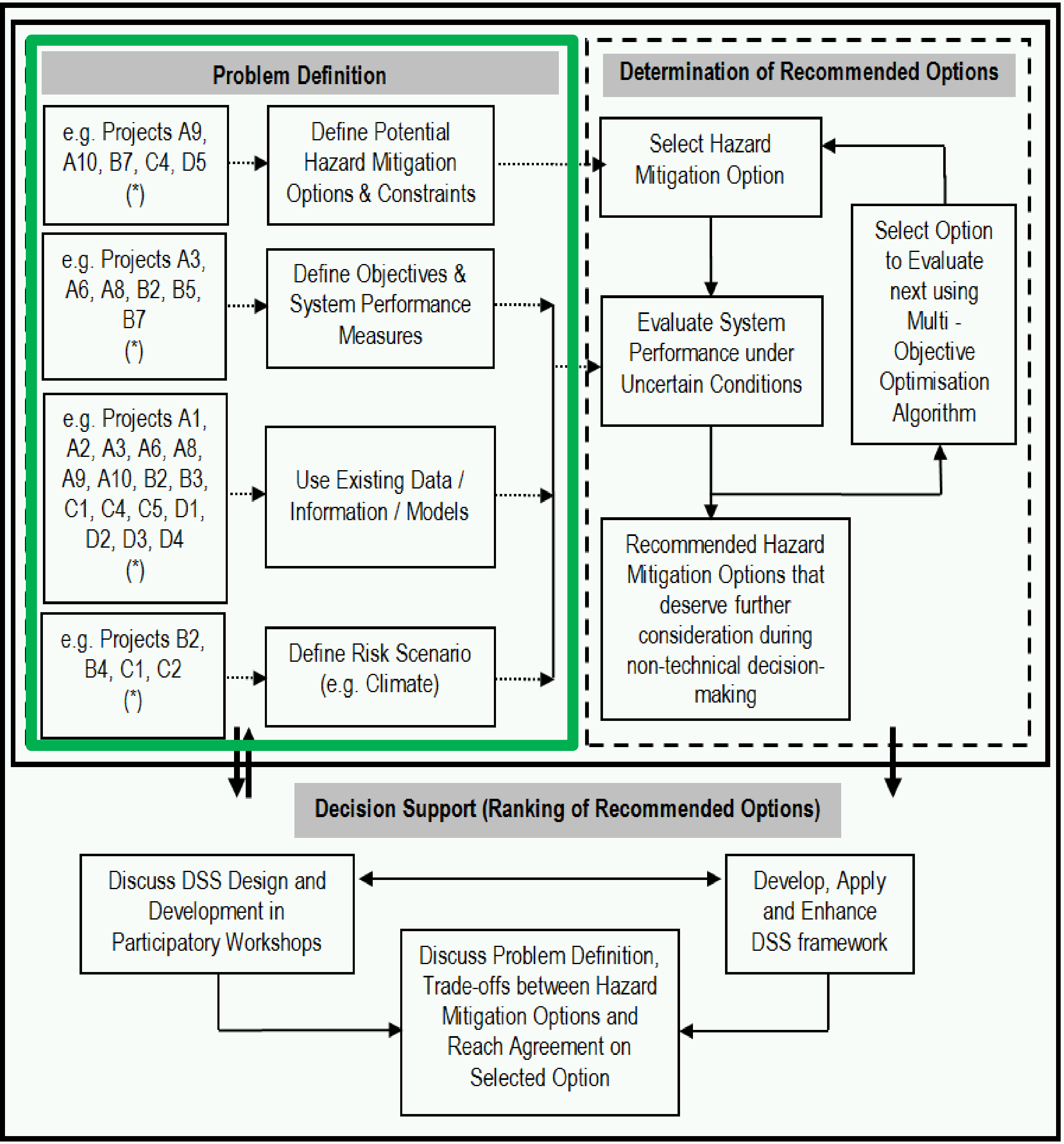
‘It is generally accepted in the emergency management community that.
one dollar spent on mitigation can save at least two dollars in recovery costs

Figures from overseas experience, particularly in the UK, have indicated that, **as much as eight recovery dollars may be saved for every one mitigation dollar spent**.’

Robert McLelland
Commonwealth Attorney General 25 March 2011



(*) = Depending on relevance to selected case studies and timely availability



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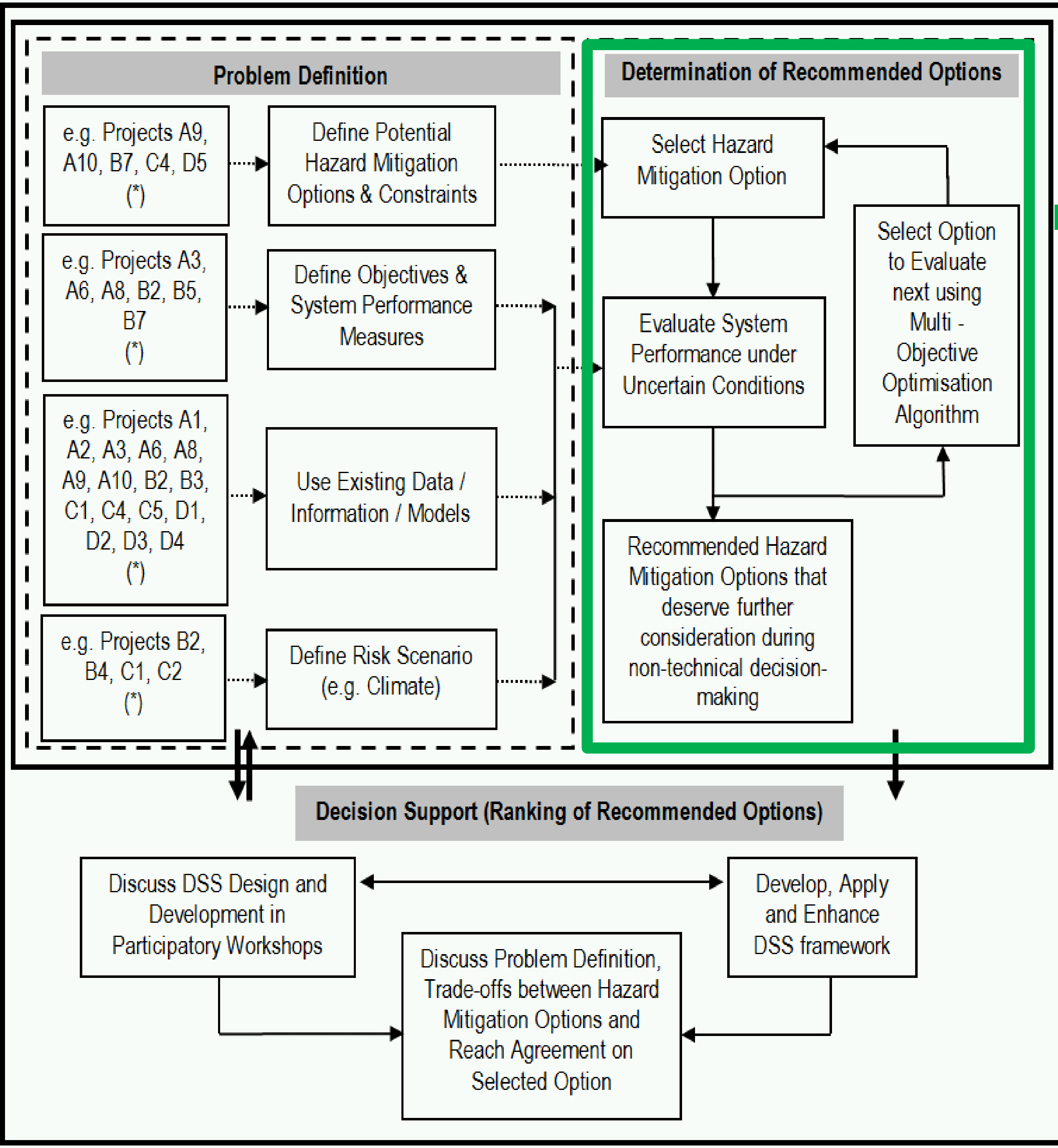

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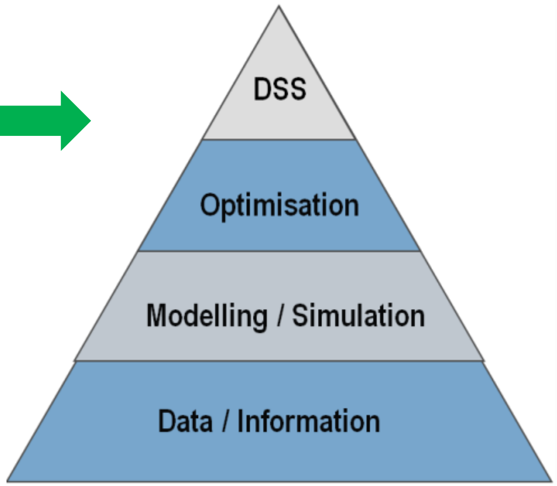

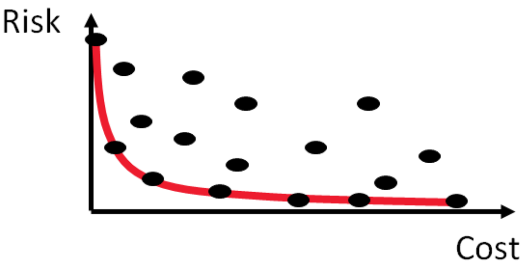

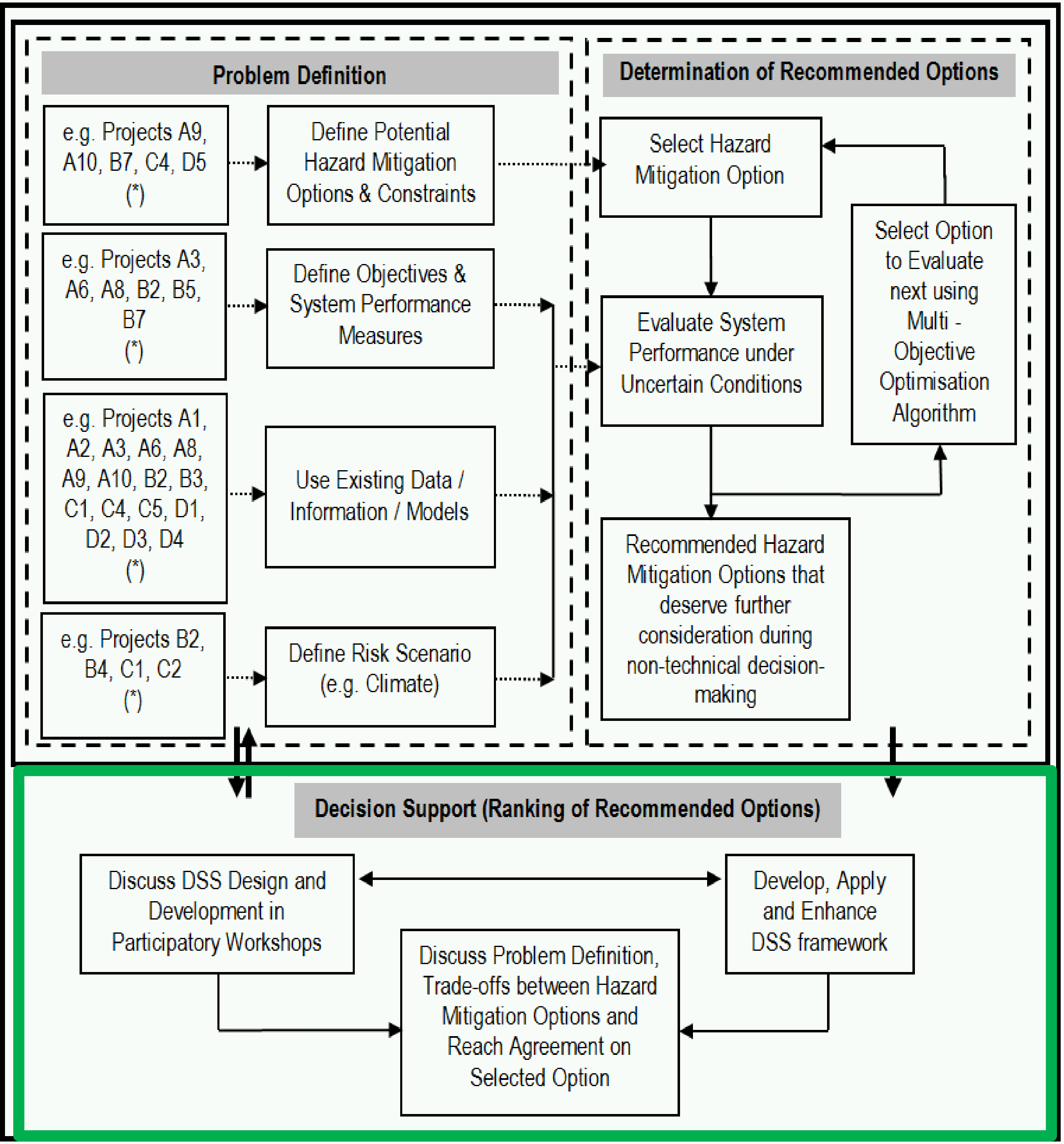

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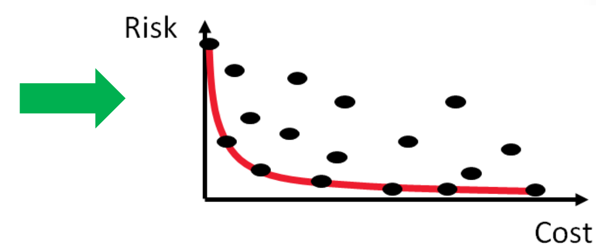

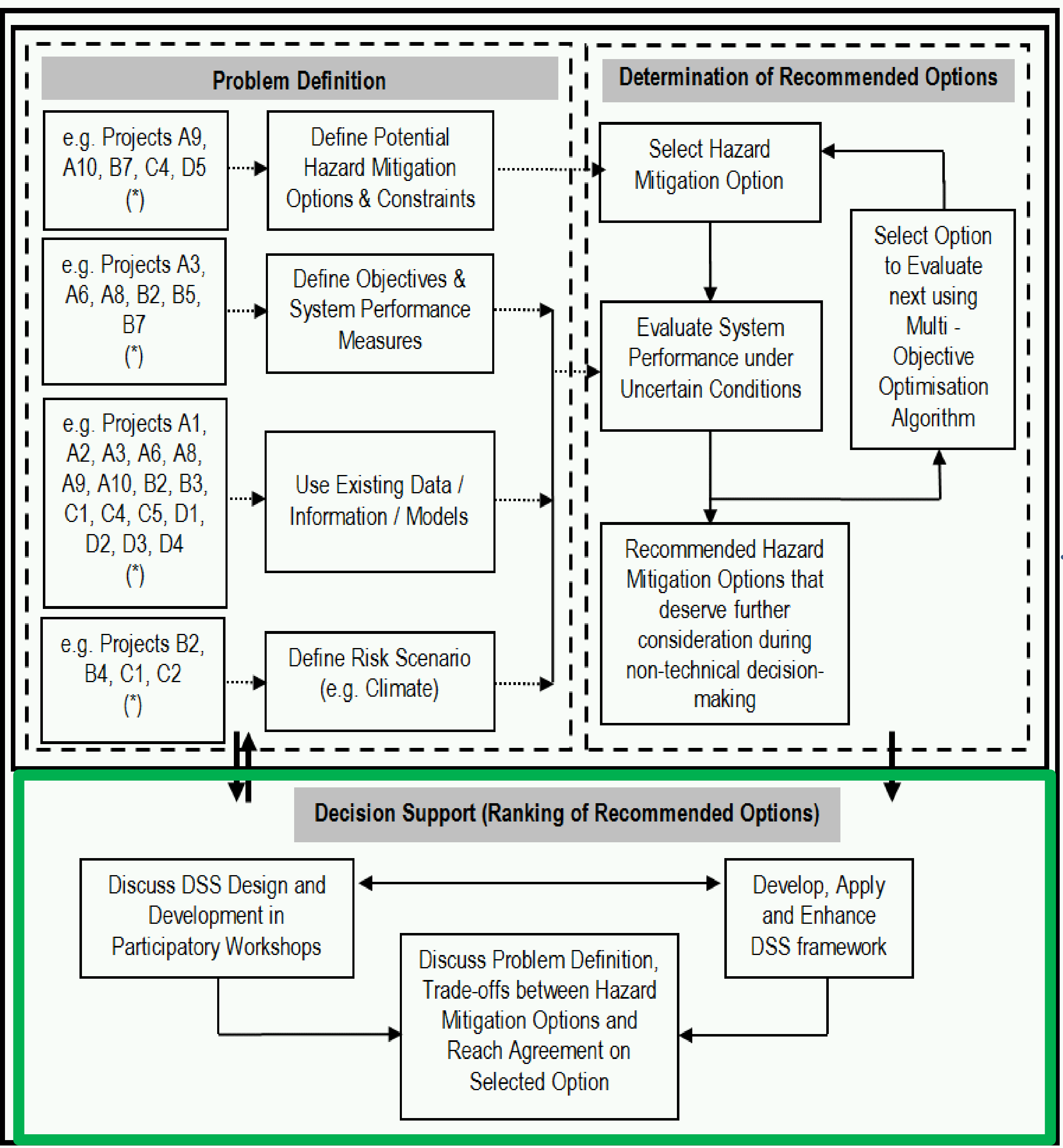

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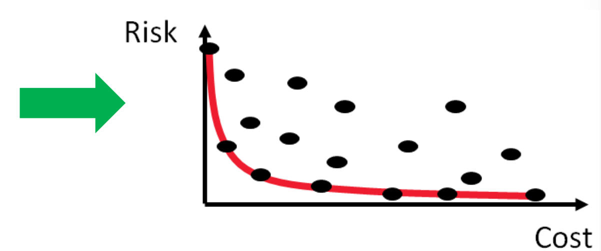
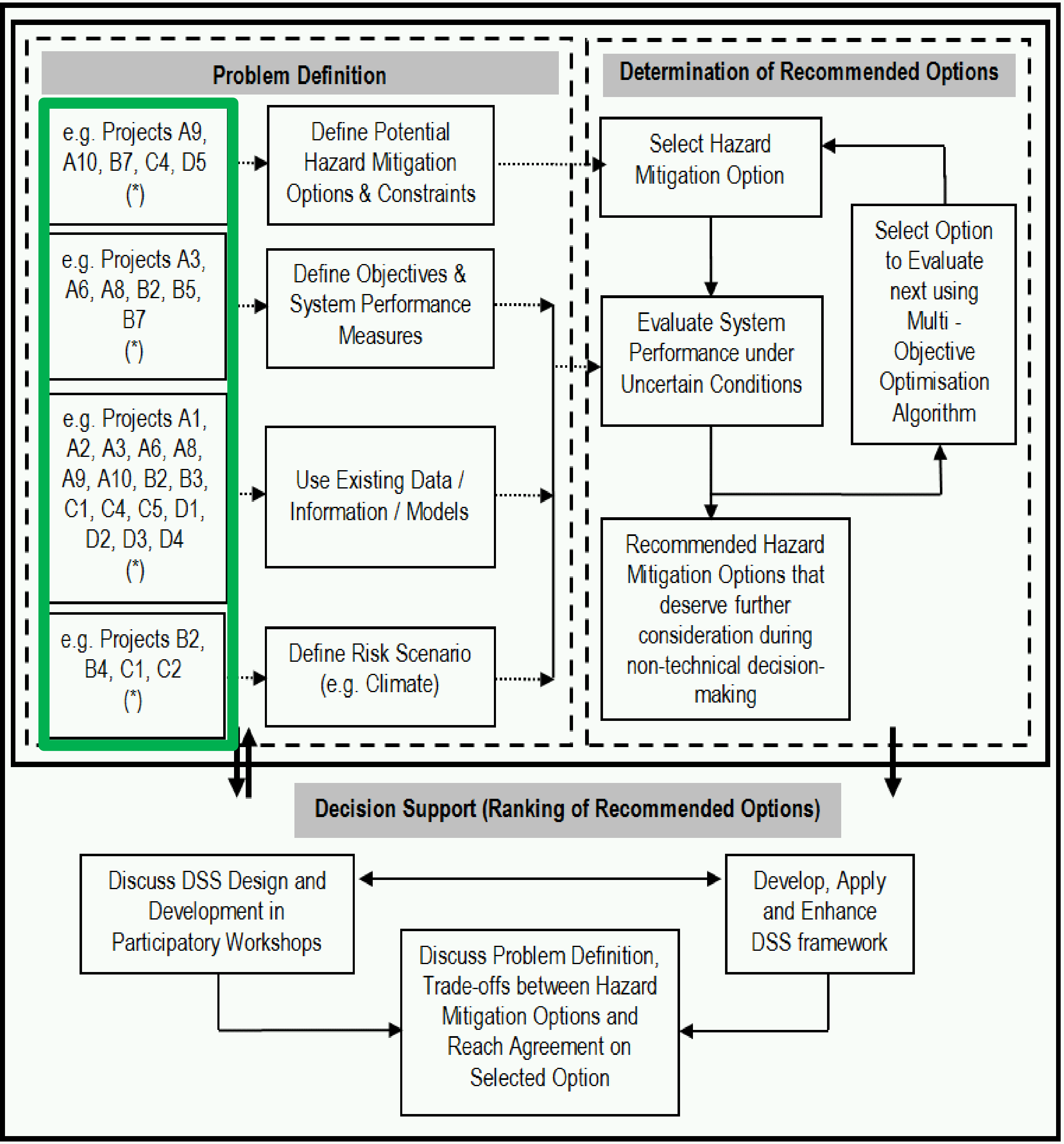
3 end-user case studies





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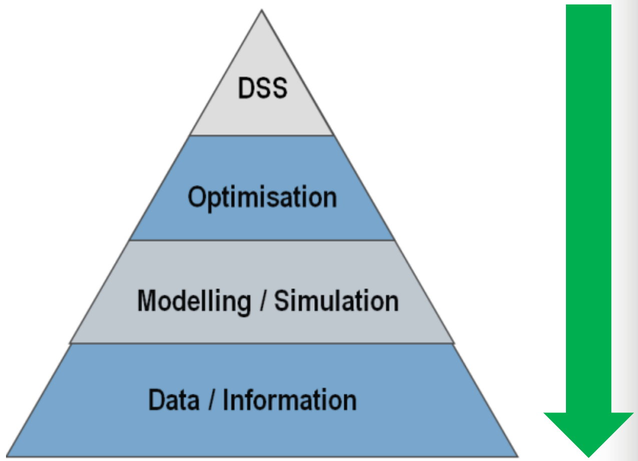

OVERVIEW OF DSS PROJECT

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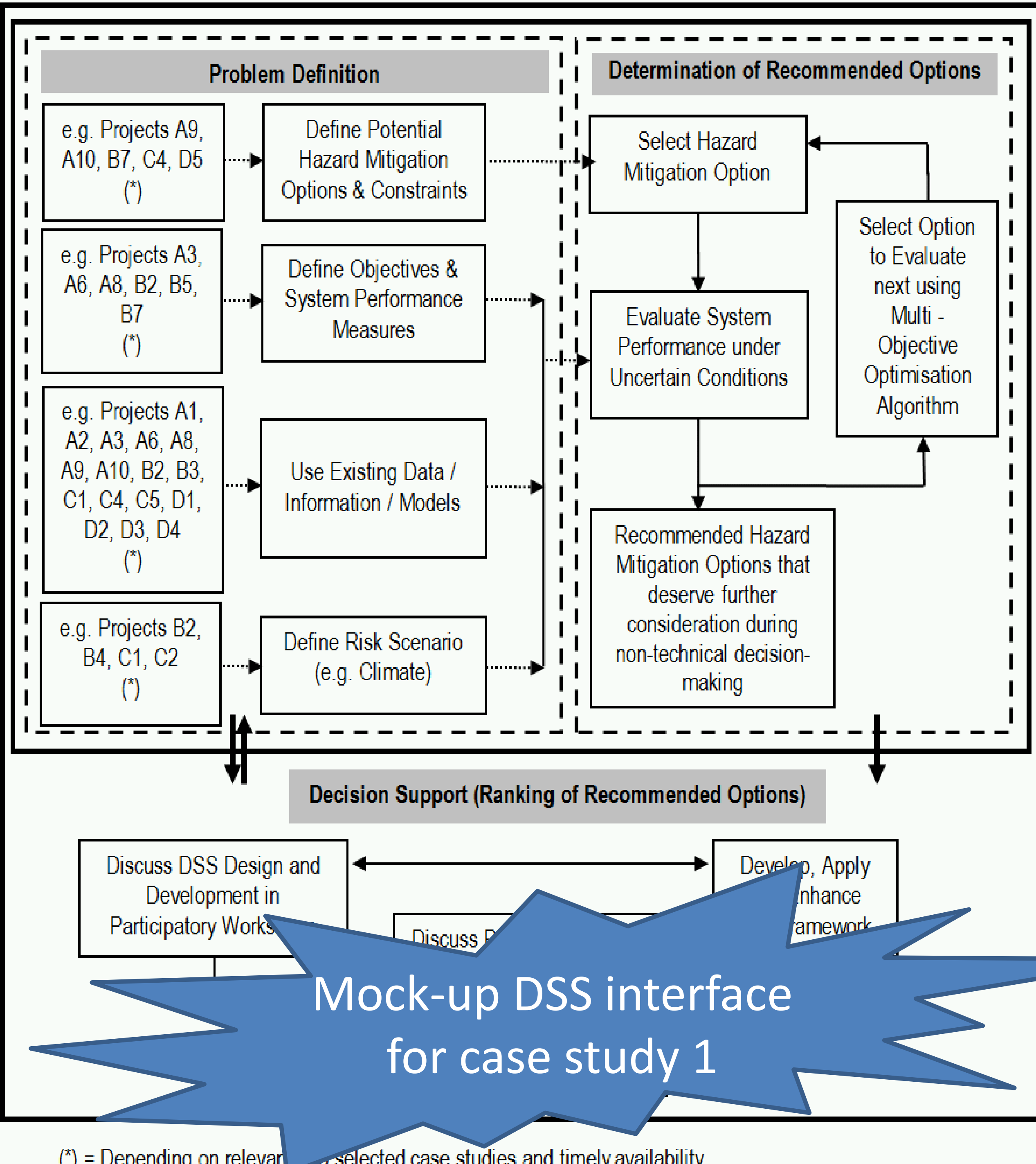
2) Conceptual Approach

3) Methodology

4) Milestones

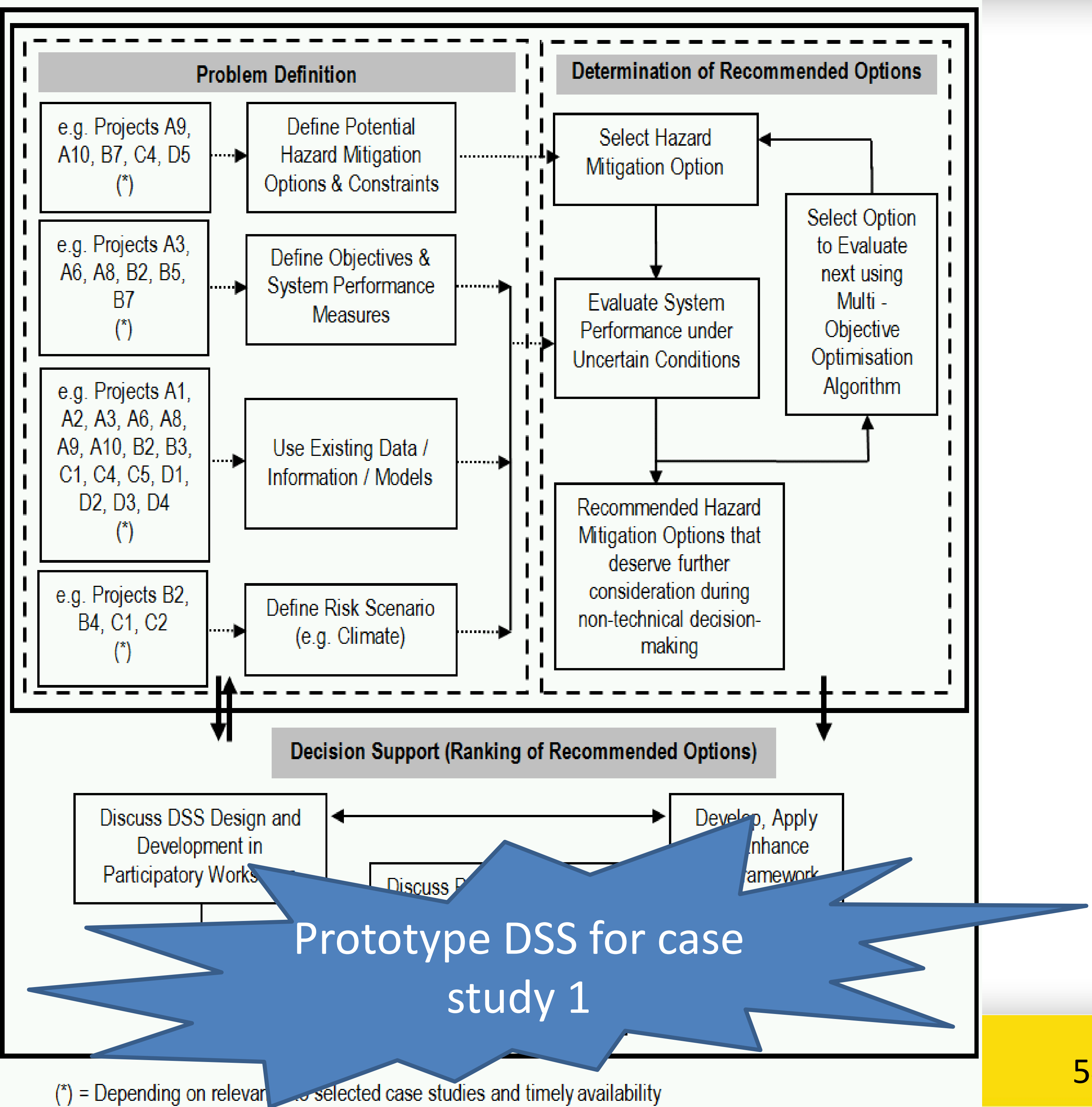
5) Personnel

Year 1 (2014)



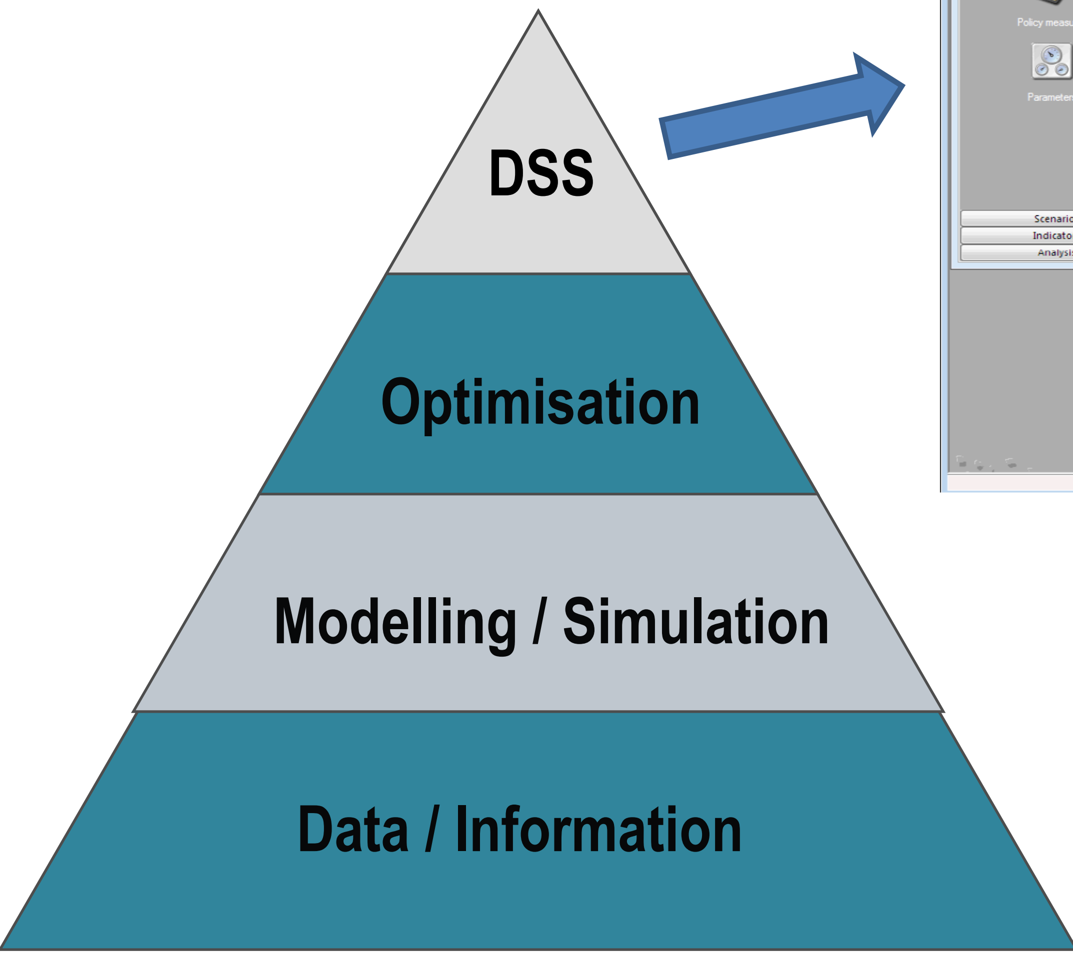
Litreview

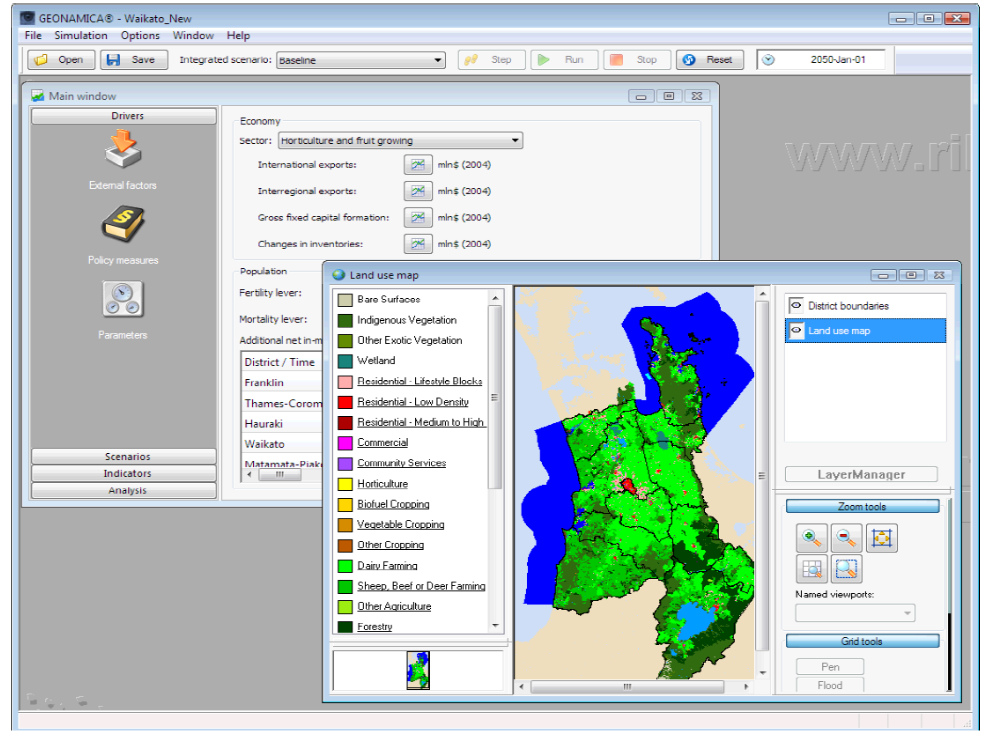
Frame-work


Problem Definition
e.g. Projects A9, A10, B7, C4, D5 (*)
Define Potential Hazard Mitigation Options & Constraints
e.g. Projects A3, A6, A8, B2, B5, B7 (*)
Define Objectives & System Performance Measures
e.g. Projects A1, A2, A3, A6, A8, A9, A10, B2, B3, C1, C4, C5, D1, D2, D3, D4 (*)
Use Existing Data / Information / Models
e.g. Projects B2, B4, C1, C2 (*)
Define Risk Scenario (e.g. Climate)
Determination of Recommended Options
Select Hazard Mitigation Option
Evaluate System Performance under Uncertain Conditions
Select Option to Evaluate next using Multi - Objective Optimisation Algorithm
Recommended Hazard Mitigation Options that deserve further consideration during non-technical decision-making
Decision Support (Ranking of Recommended Options)
Discuss DSS Design and Development in Participatory Works
Discuss
Develo, Apply
nhance
amework
Prototype DSS for case study 1
(*) = Depending on relevan
selected case studies and timely availability

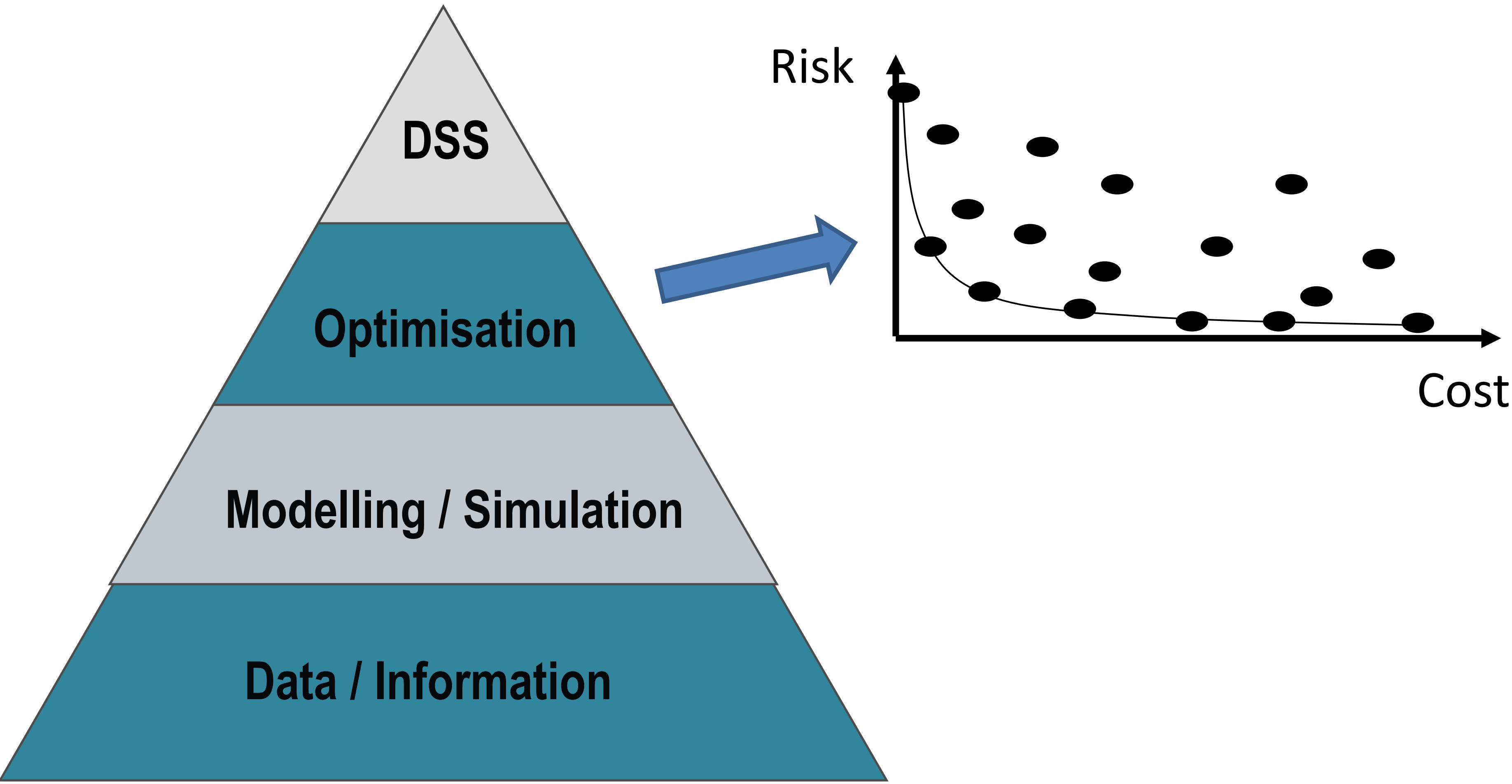
Year 2 (2015)

Decision Support

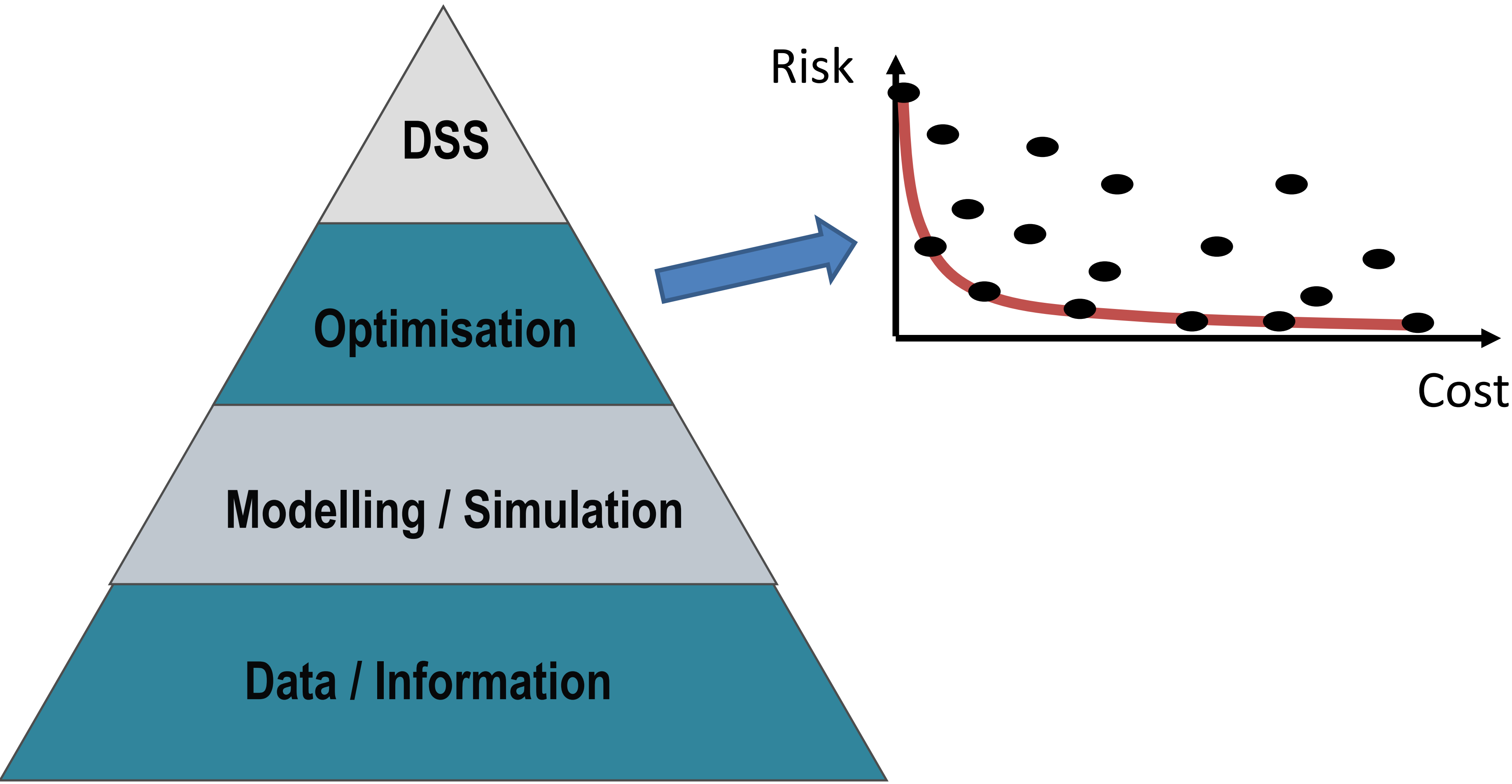




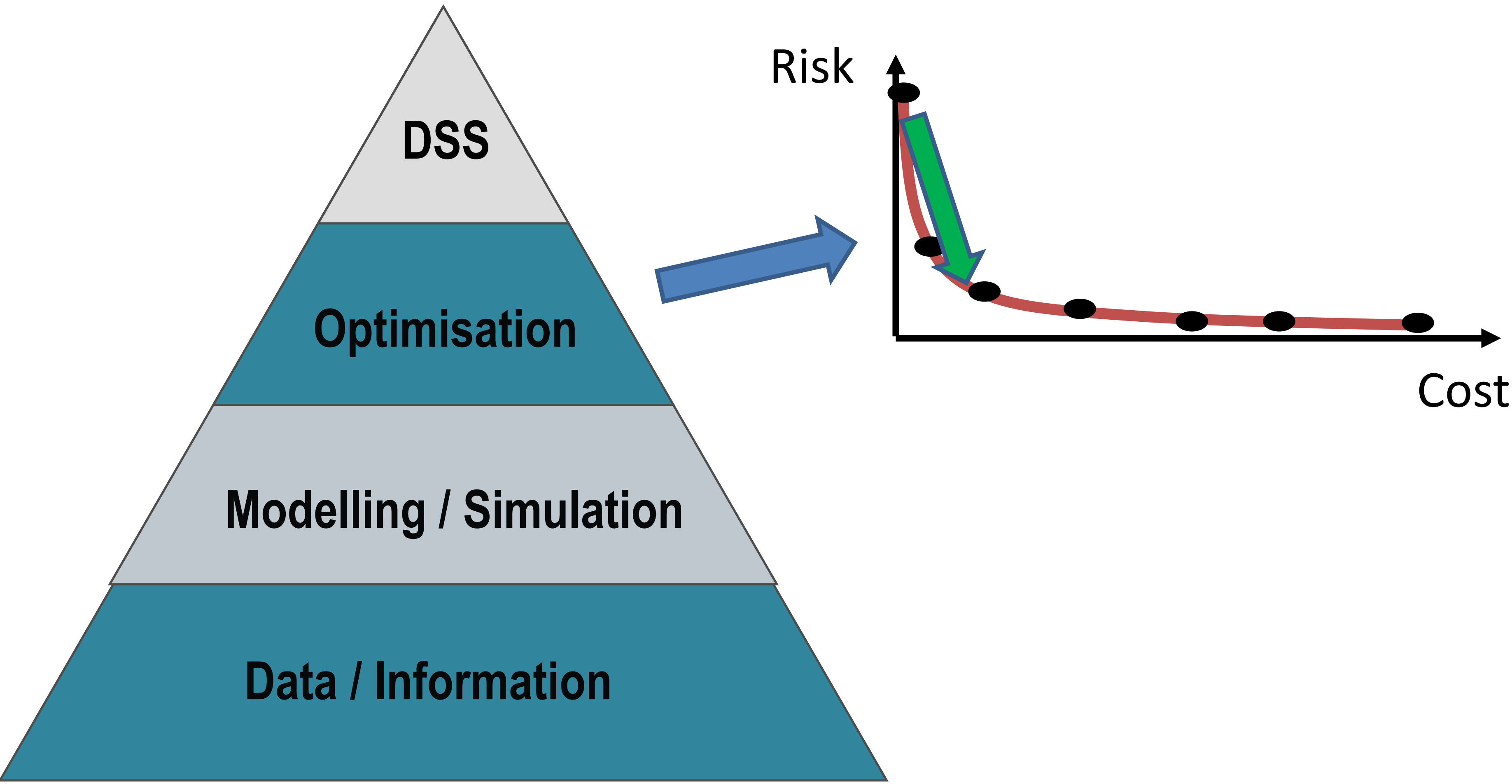
Decision Support



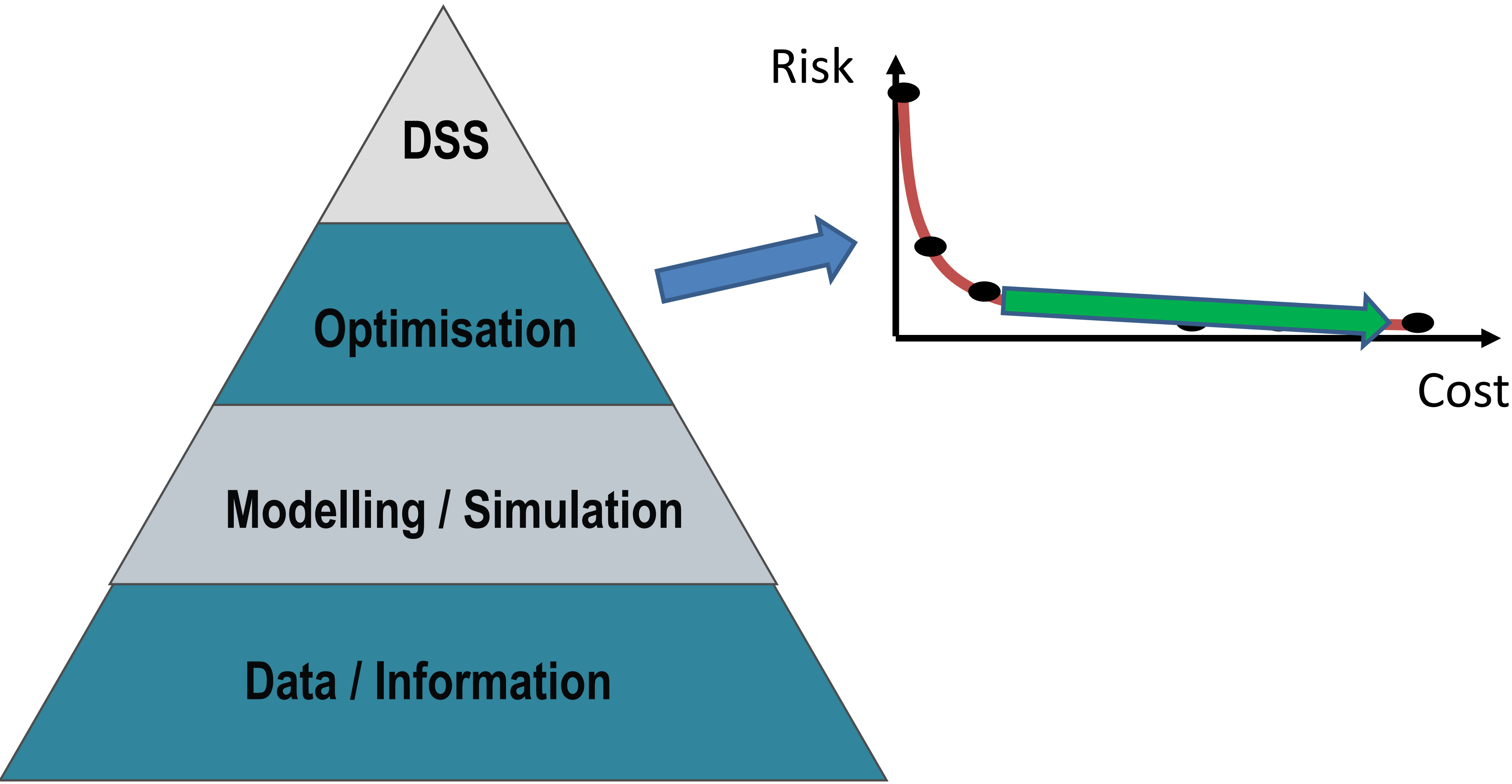
Decision Support



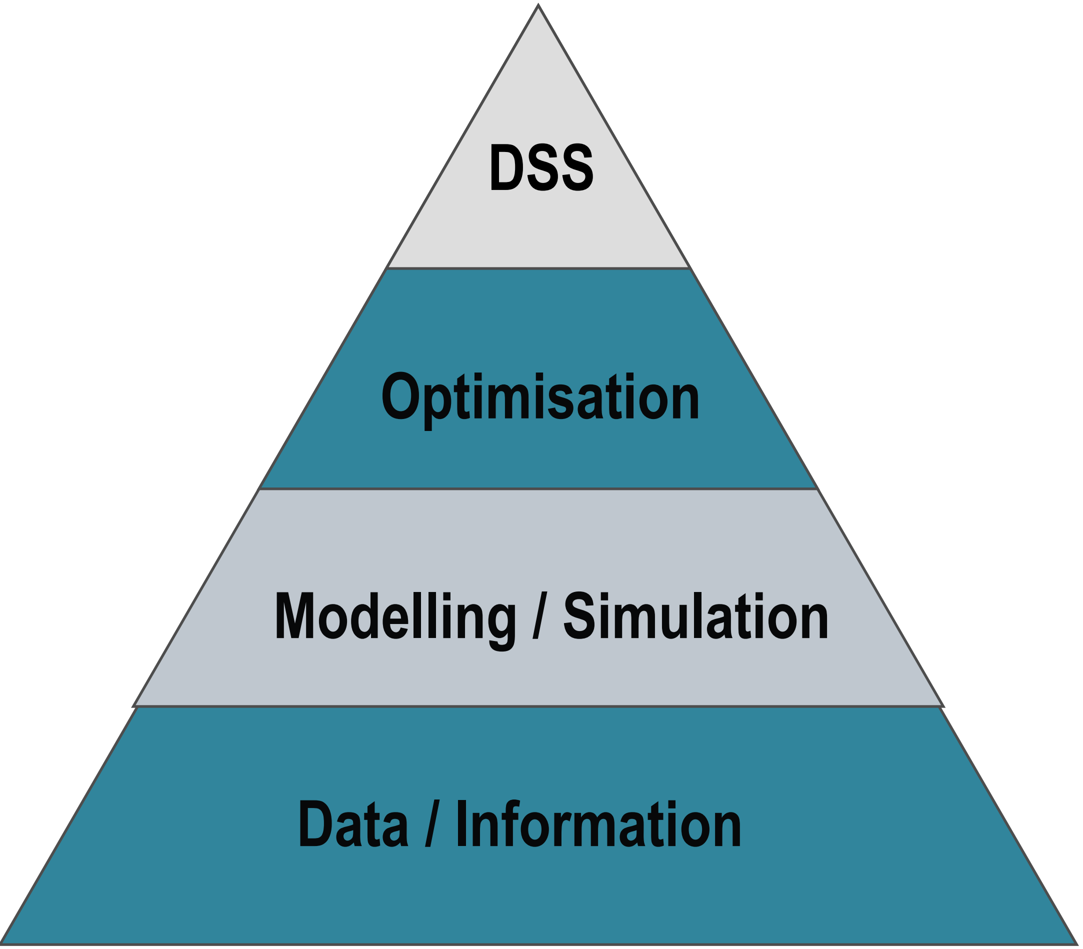
Decision Support



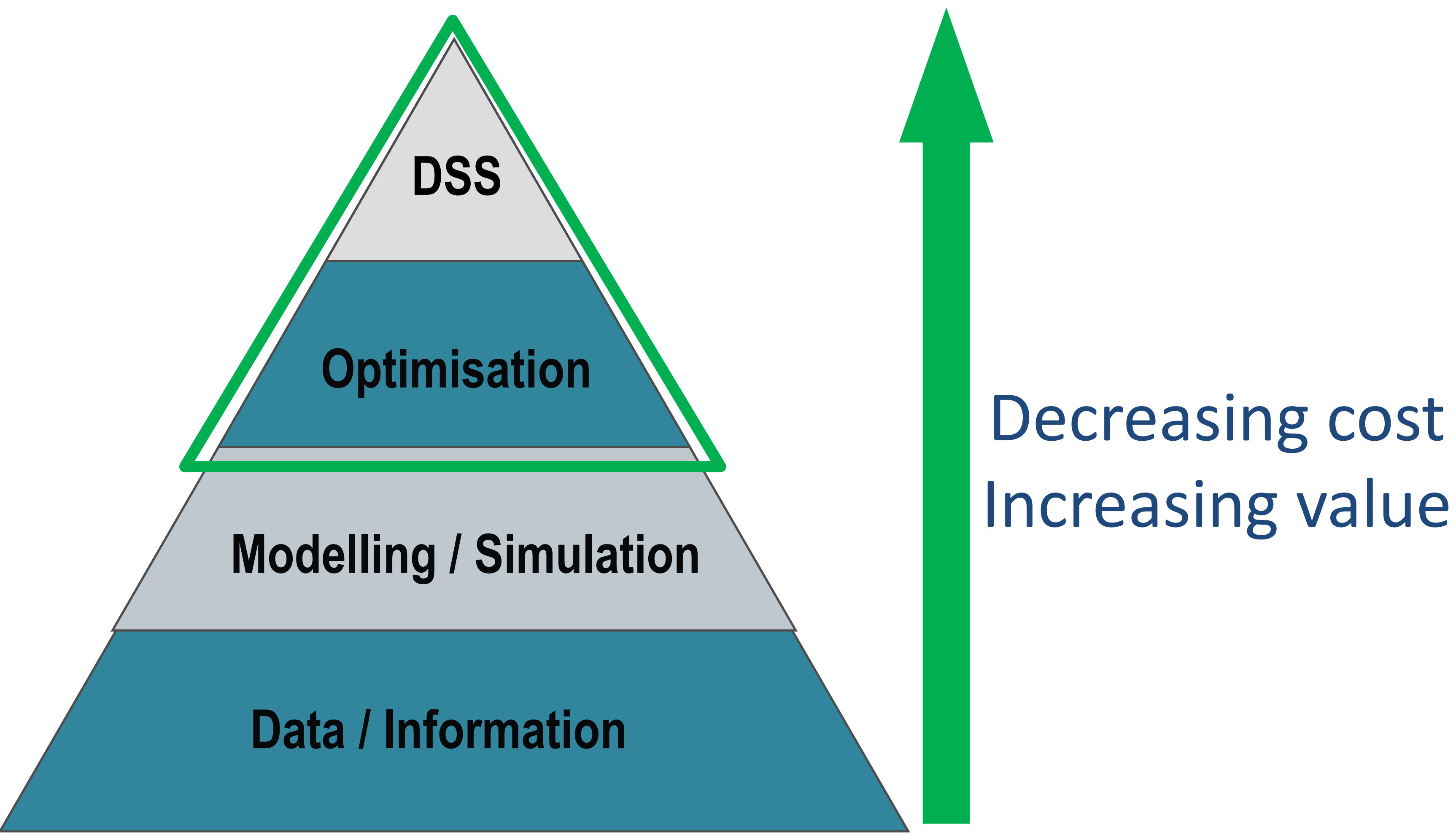
Decision Support



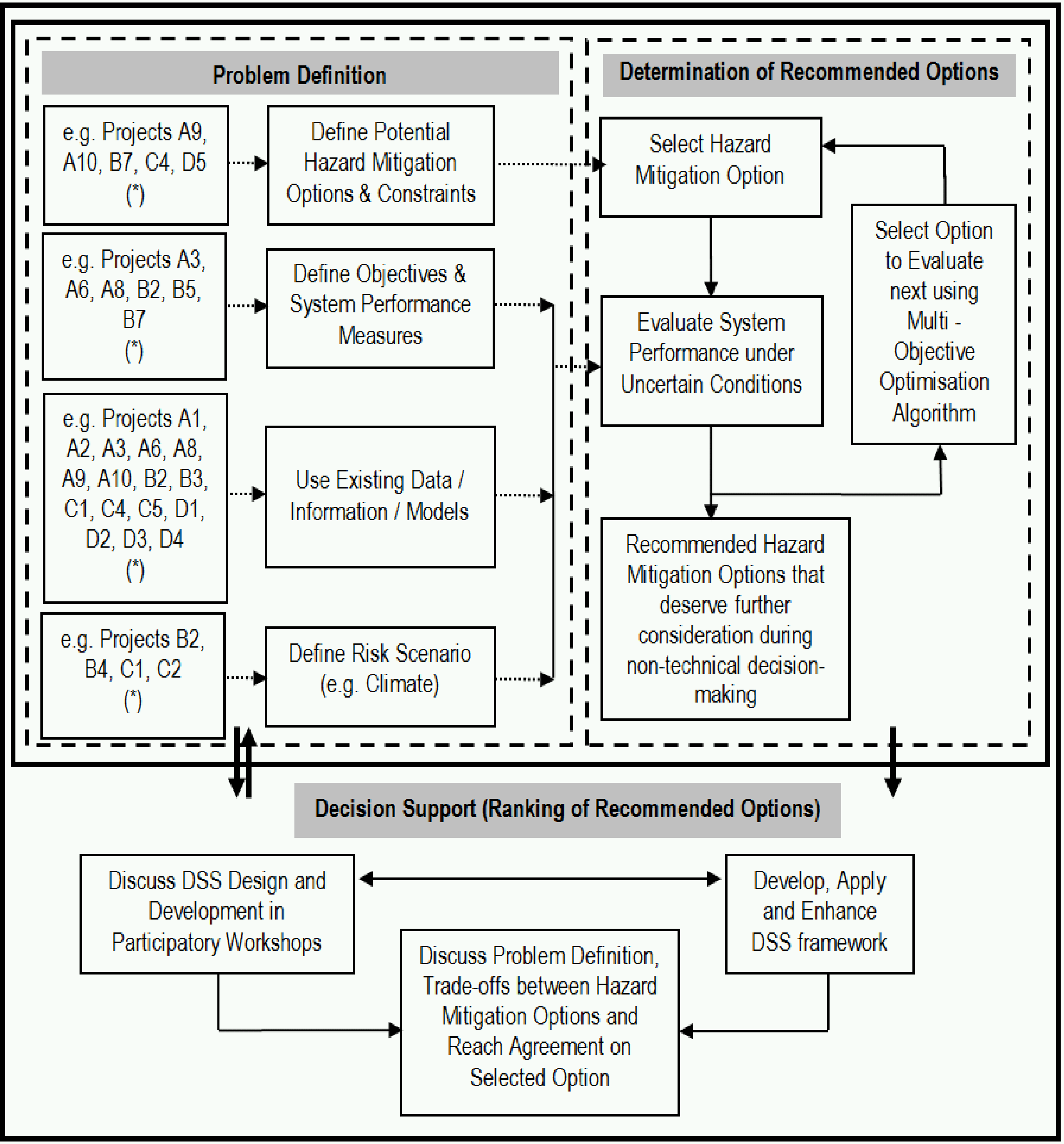
Decision Support



Decision Support



Year 3 (2016)



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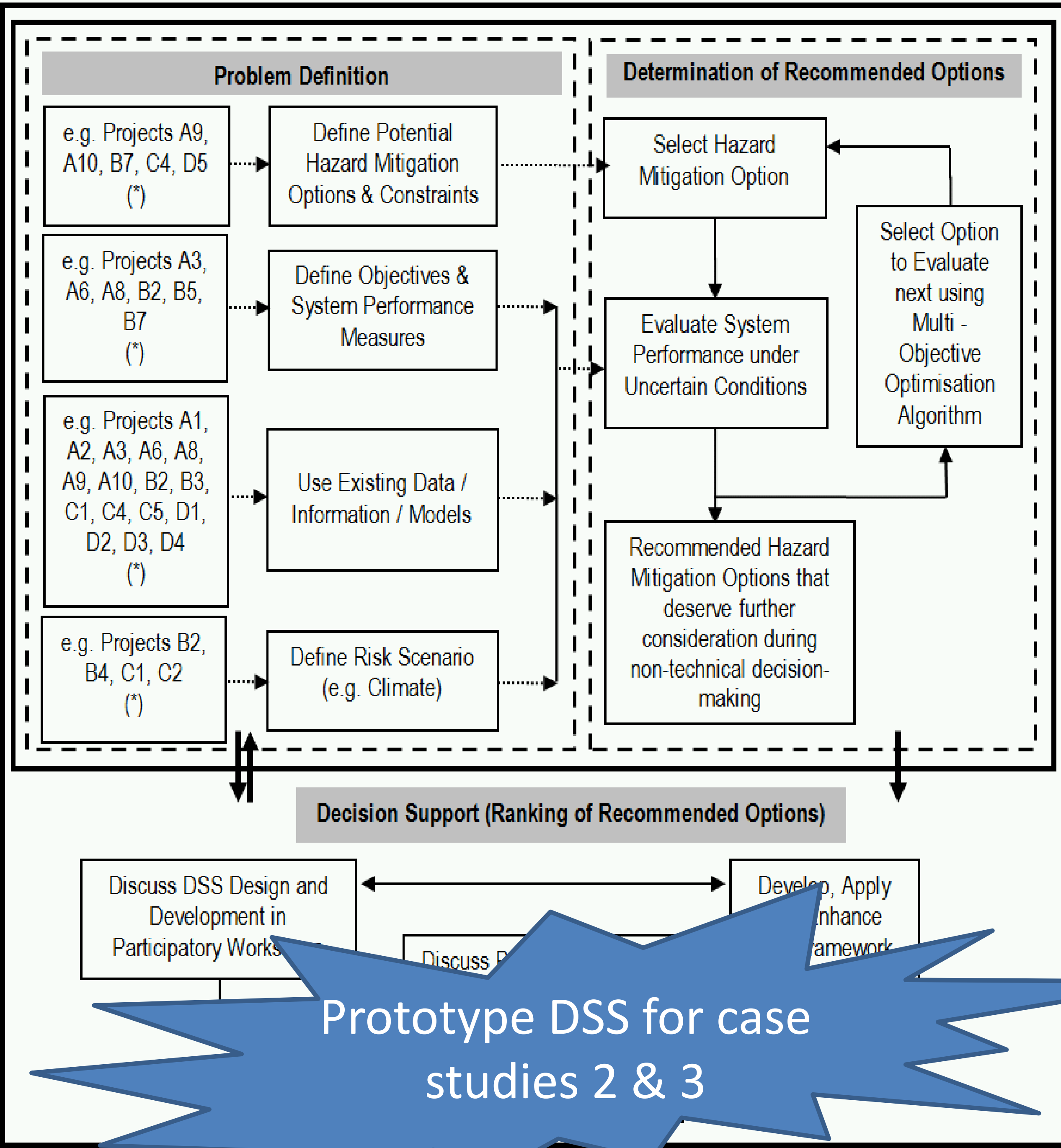

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Year 4 (2017)

2 Journal Papers

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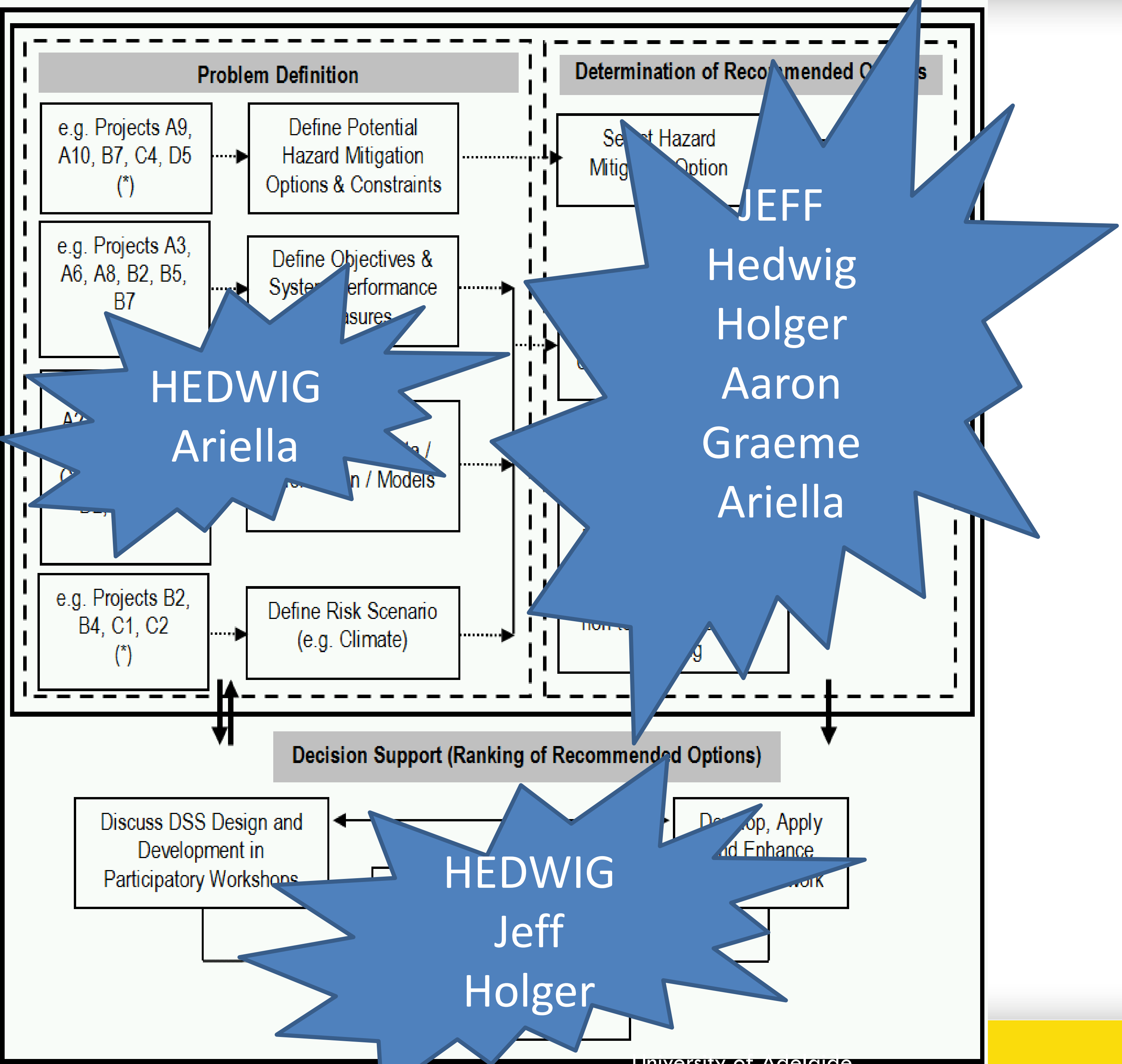

University of Adelaide

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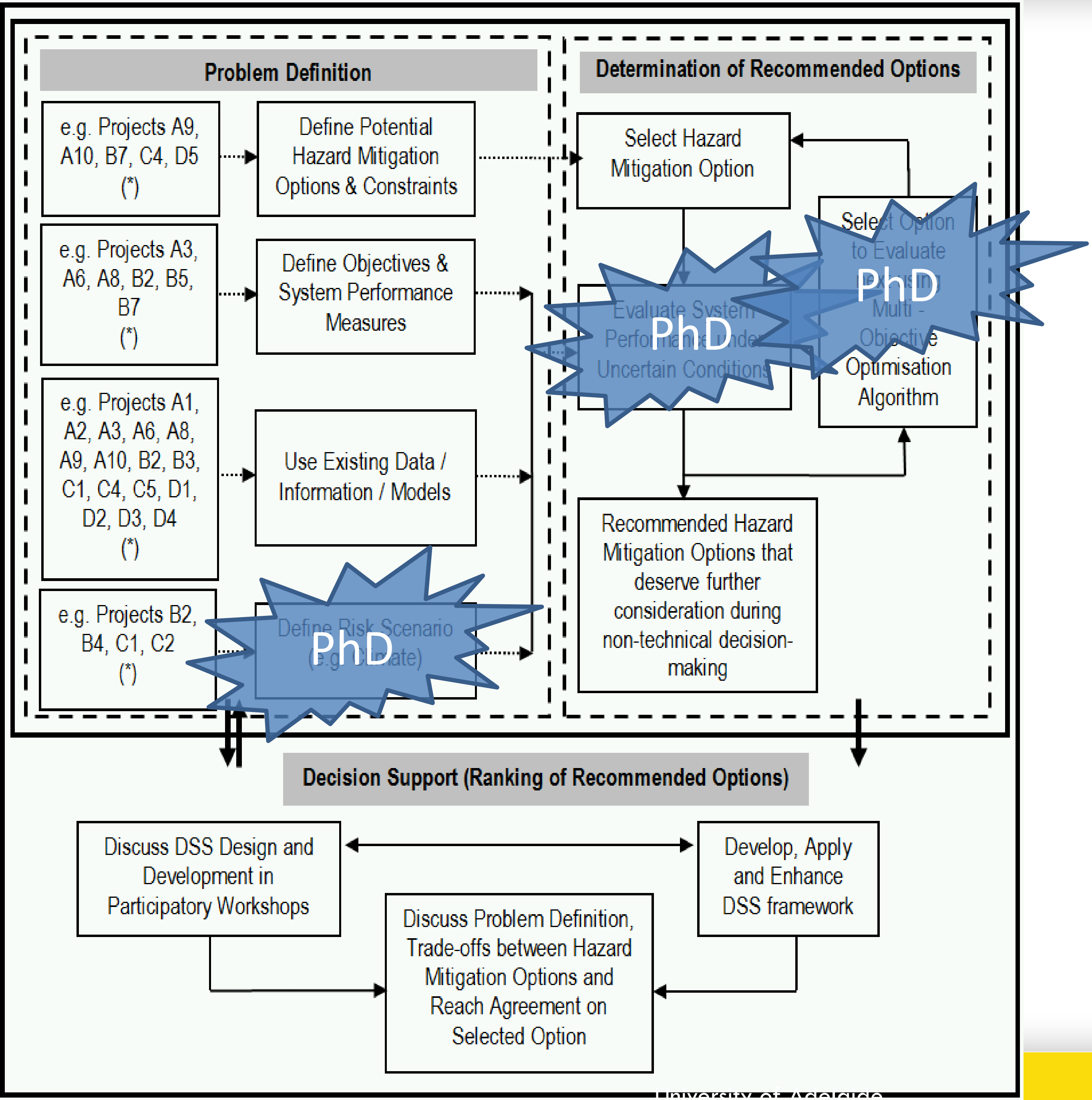

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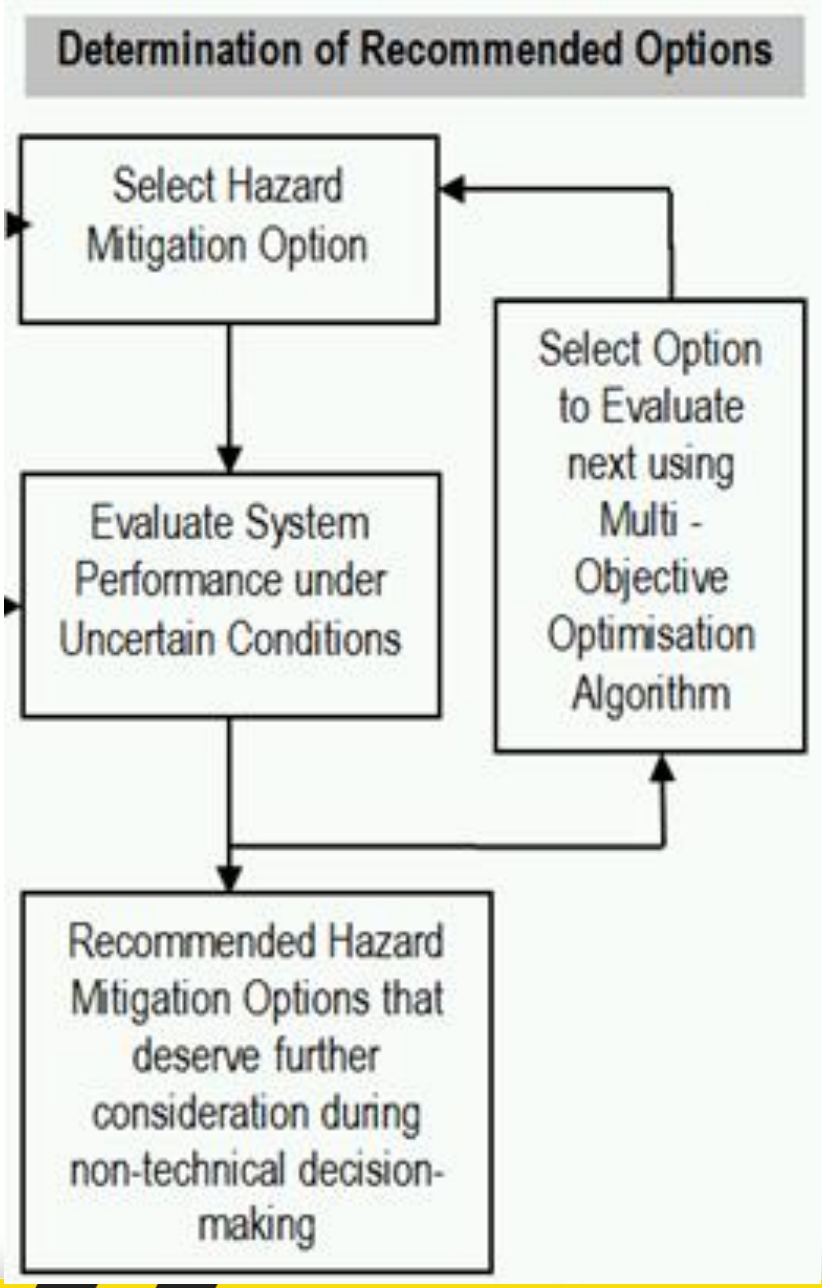
PRESENTATION OUTLINE

1) Structure of CRC

2) Overview of DSS Project

3) Overview of Evolutionary Algorithms

4) Evolutionary Algorithm Research Challenges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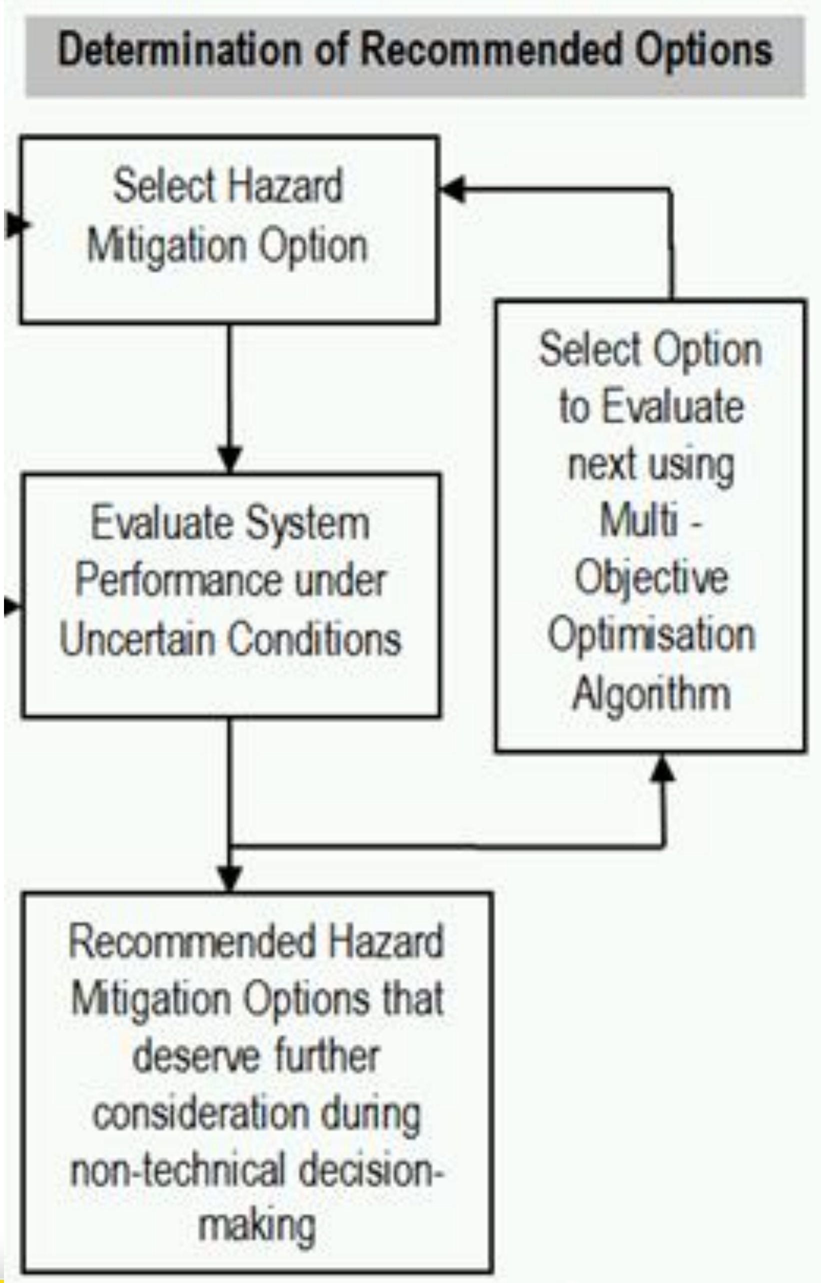
Select Option to Evaluate next using Multi - Objective Optimisation Algorithm
Evaluate System Performance under Uncertain Conditions
Recommended Hazard Mitigation Options that deserve further consideration during non-technical decision-making


Determination of Recommended Options
Select Hazard Mitigation Option
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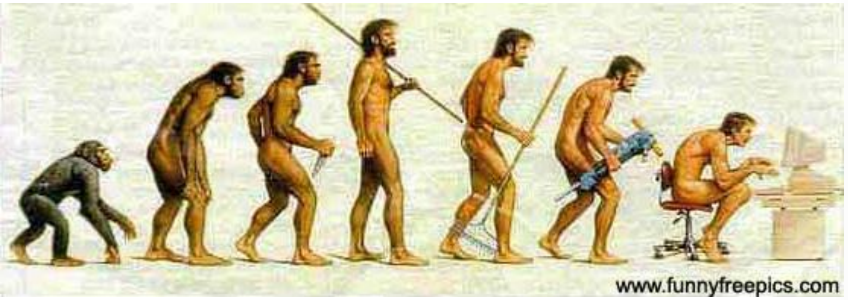
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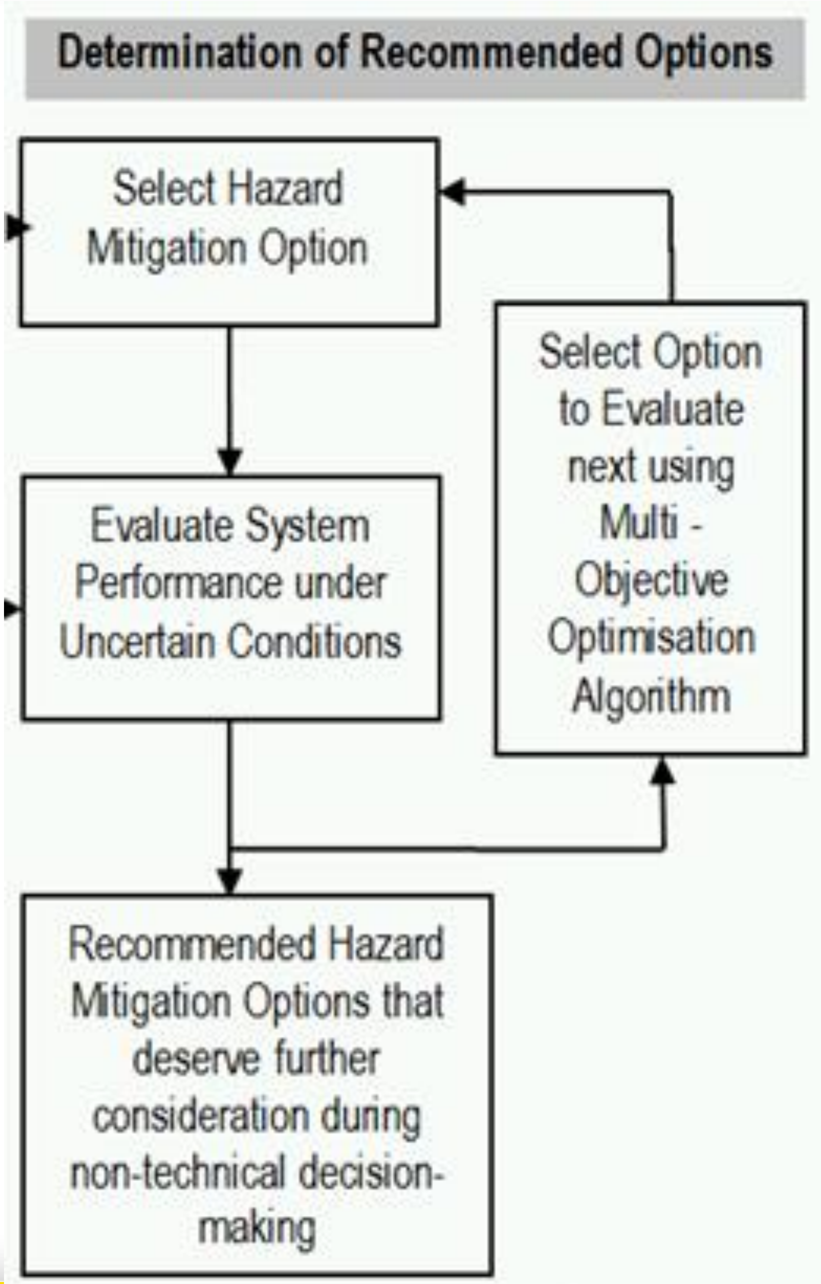
EVOLUTIONARY ALGORITHMS

1) Search from a **population of decision variable sets** simultaneously

2) Use **probabilistic**, rather than deterministic, rules

3) Use value of **objective function** directly (can link with simulation models)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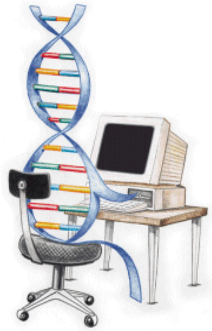
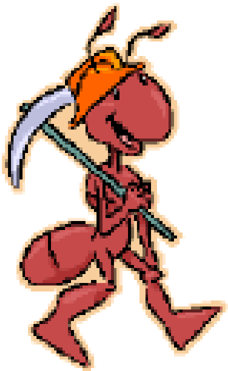
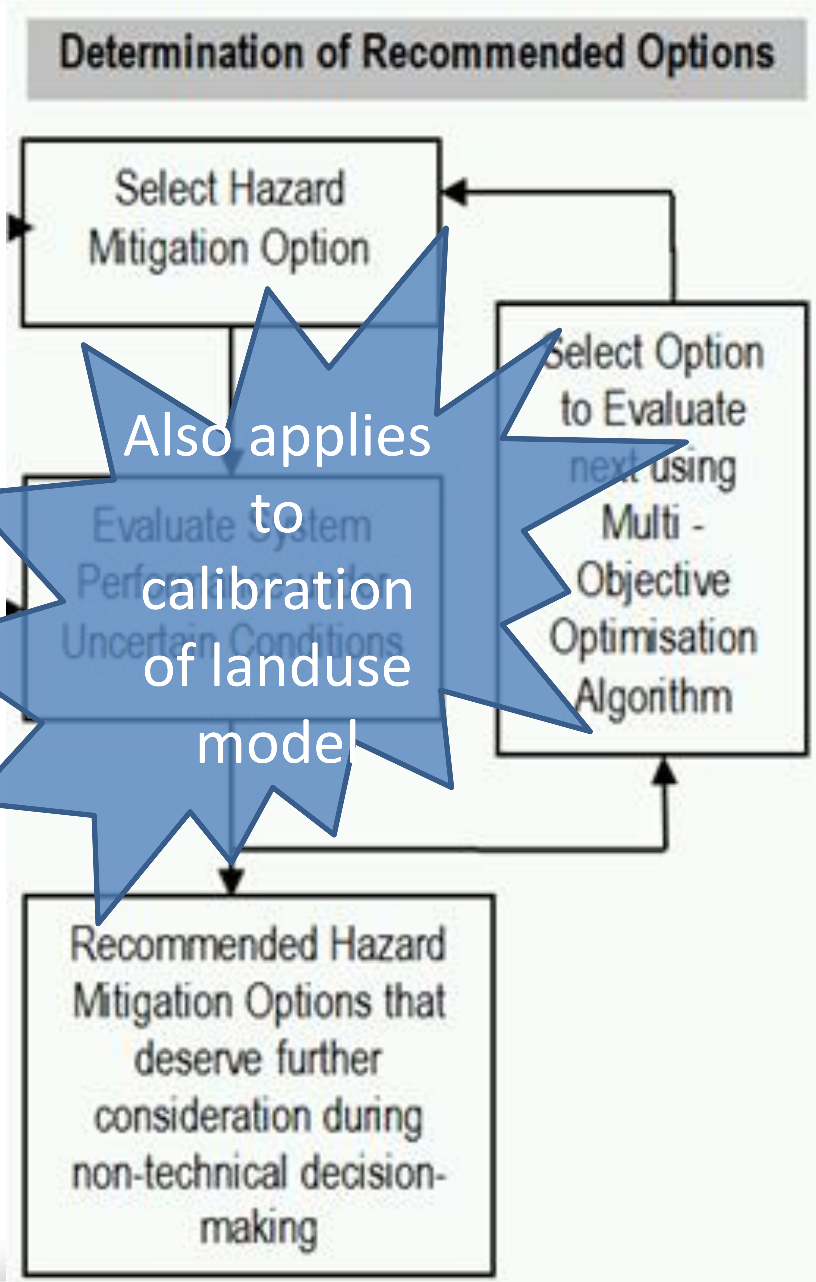
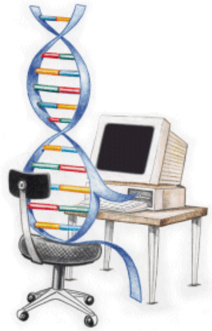
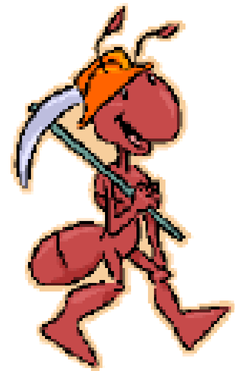






Also applies to calibration of landuse model





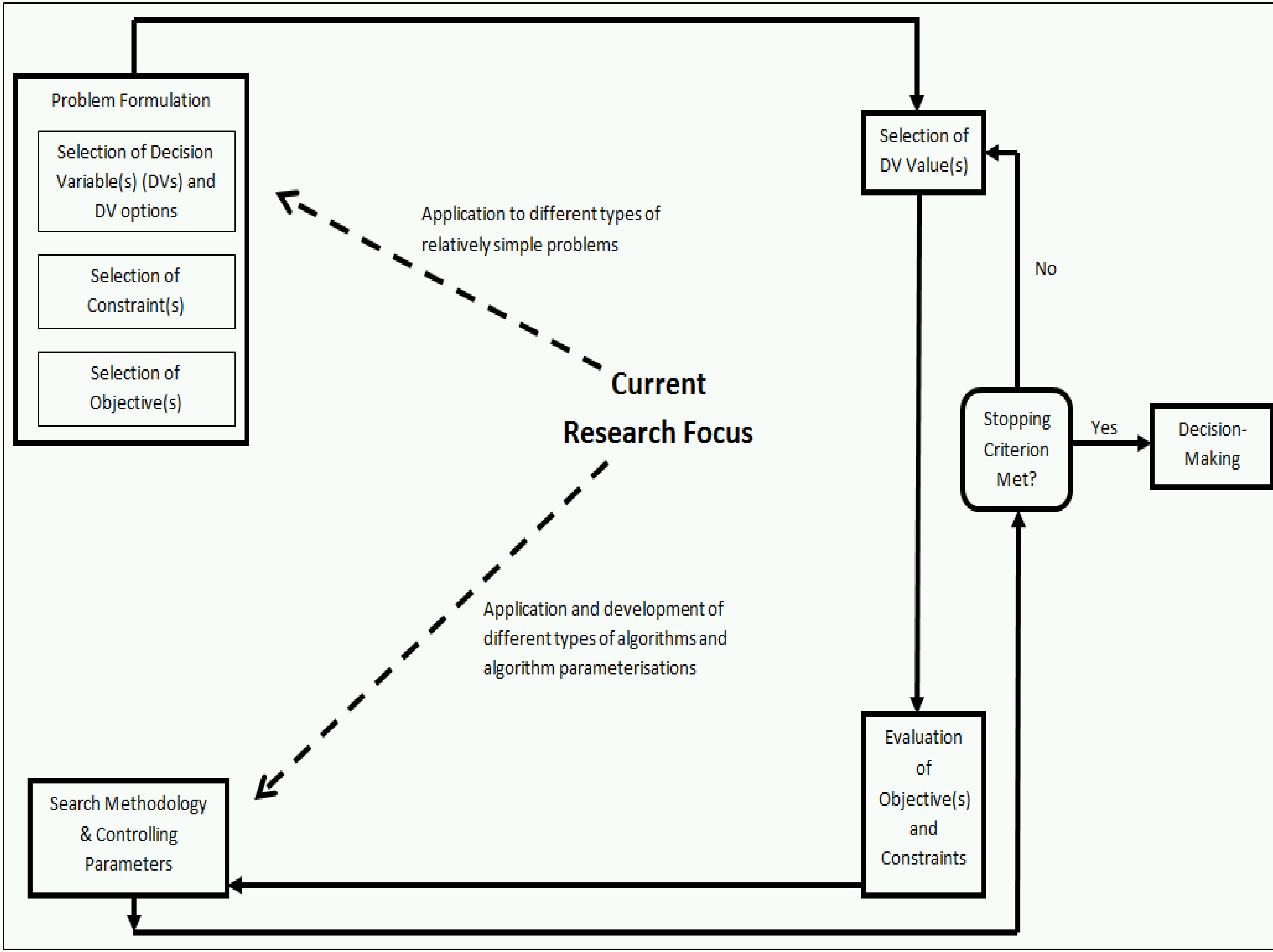
PRESENTATION OUTLINE

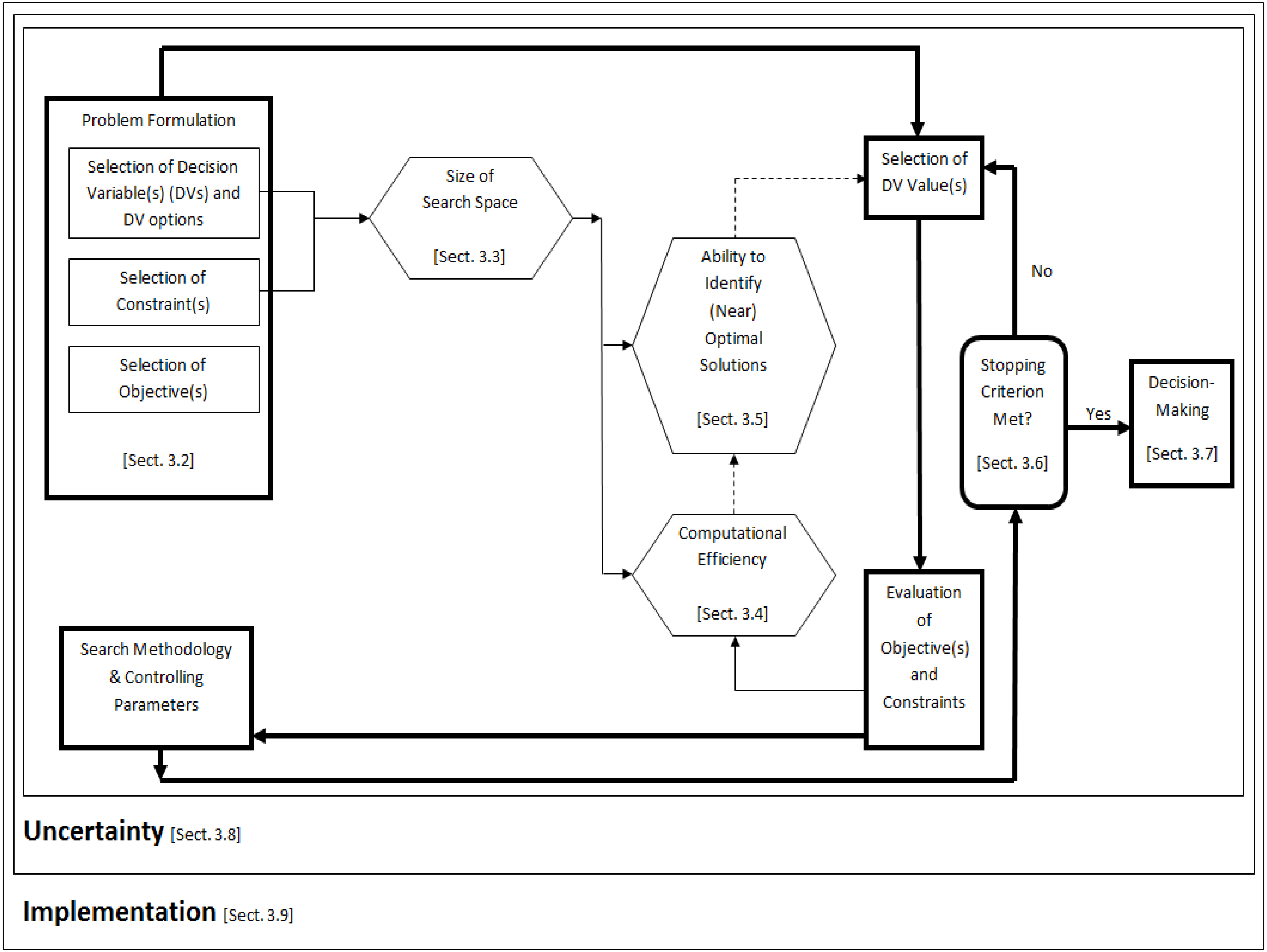
1) Structure of CRC

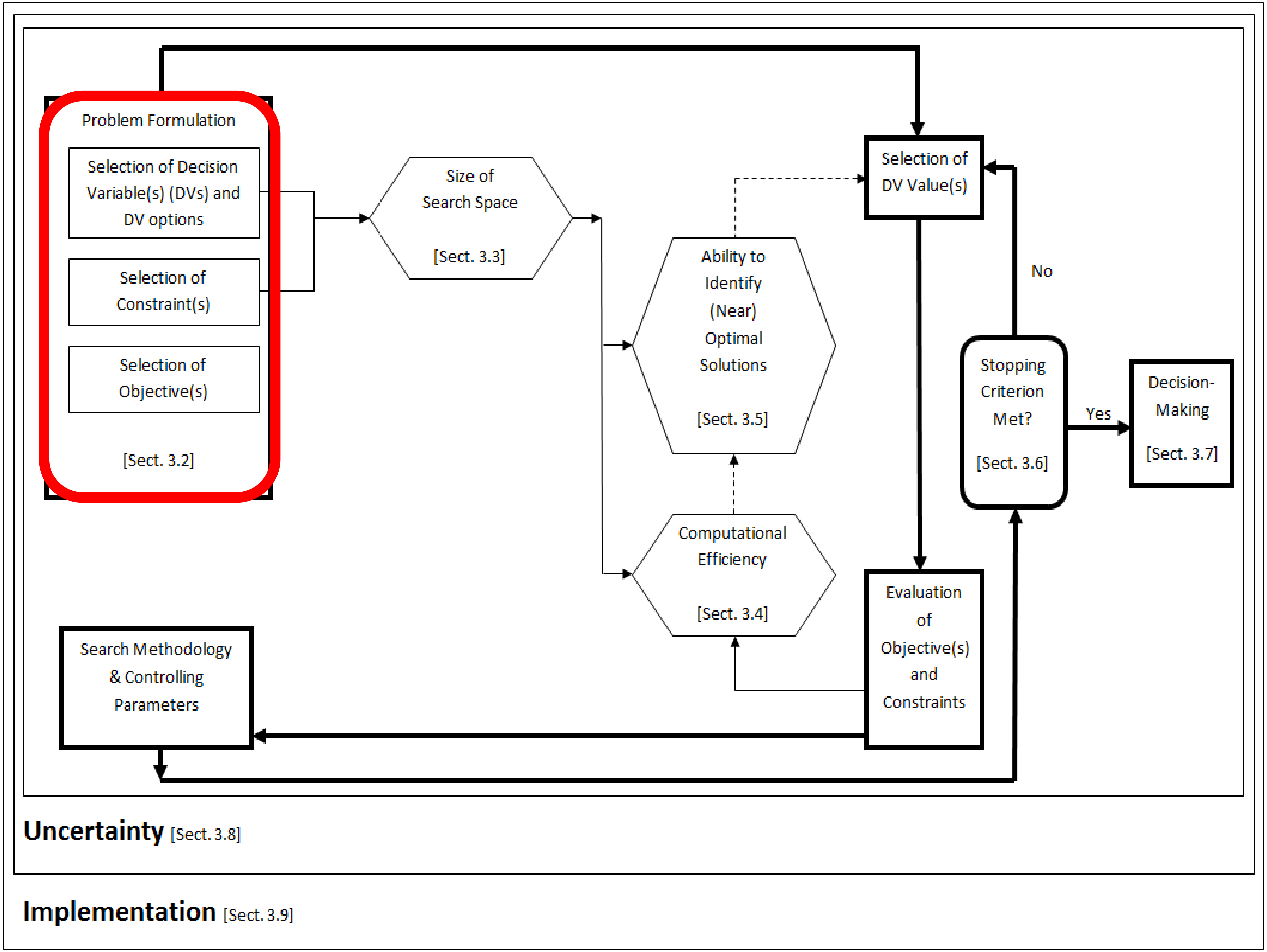
2) Overview of DSS Project

3) Overview of Evolutionary Algorithms

4) Evolutionary Algorithm Research Challenges


Problem Formulation
Selection of Decision Variable(s) (DVs) and DV options
Selection of Constraint(s)
Selection of Objective(s)
Application to different types of relatively simple problems
Current Research Focus
Application and development of different types of algorithms and algorithm parameterisations
Search Methodology & Controlling Parameters
Selection of DV Value(s)
No
Stopping Criterion Met?
Yes
Decision-Making
Evaluation of Objective(s) and Constraints


Problem Formulation
Selection of Decision Variable(s) (DVs) and DV options
Selection of Constraint(s)
Selection of Objective(s)
[Sect. 3.2]
Size of Search Space
[Sect. 3.3]
Ability to Identify (Near) Optimal Solutions
[Sect. 3.5]
Computational Efficiency
[Sect. 3.4]
Selection of DV Value(s)
Evaluation of Objective(s) and Constraints
No
Stopping Criterion Met?
[Sect. 3.6]
Yes
Decision-Making
[Sect. 3.7]
Search Methodology & Controlling Parameters
Uncertainty [Sect. 3.8]
Implementation [Sect. 3.9]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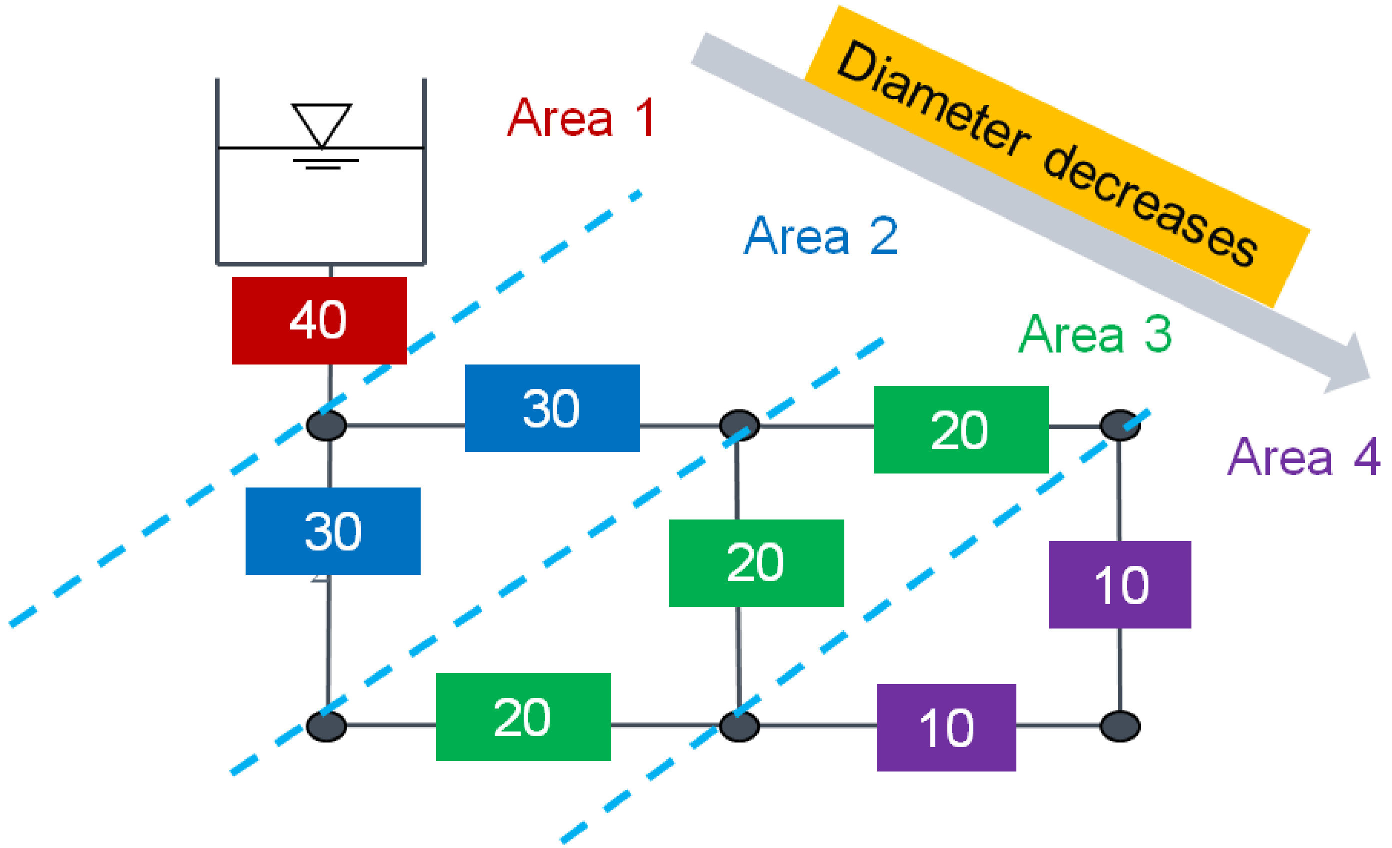
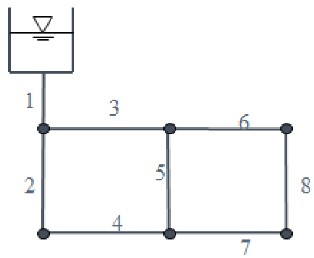
Seeding Initial Population



Example network

Seeding Initial Population



Example network

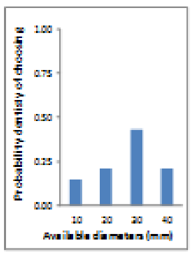
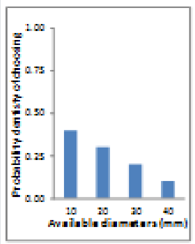
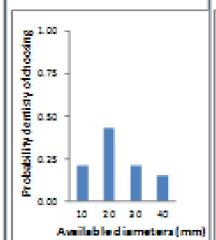
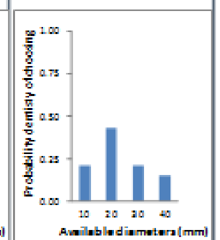
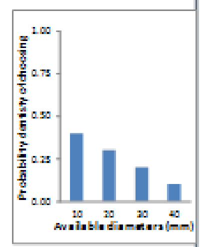
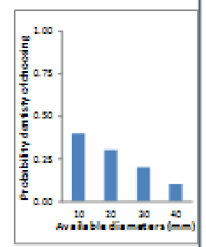
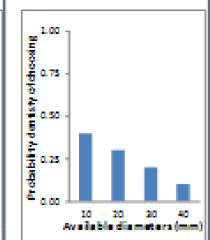
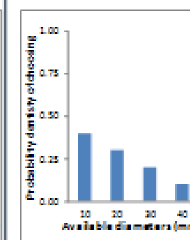
Options of diameters (mm)			
10	20	30	40

Solution pool

Solution	1	2	3	4
Total cost ($ million)	3.1	2.9	2.7	2.4
Velocity threshold (v) (m/s)	0.1	0.2	0.3	0.4
Pipe 1 (mm)	40	30	30	30
Pipe 2 (mm)	20	20	20	10
Pipe 3 (mm)	30	20	20	20
Pipe 4 (mm)	20	20	20	20
Pipe 5 (mm)	10	10	10	10
Pipe 6 (mm)	20	20	10	10
Pipe 7 (mm)	10	10	10	10
Pipe 8 (mm)	10	10	10	10

Approximate optimal Solution

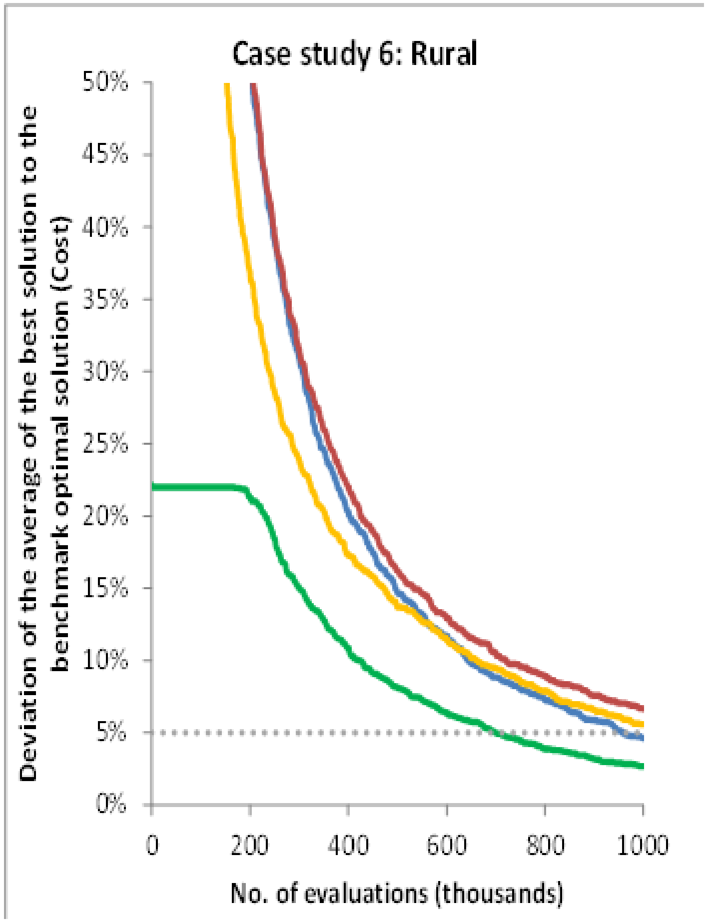
Seeding Initial Population

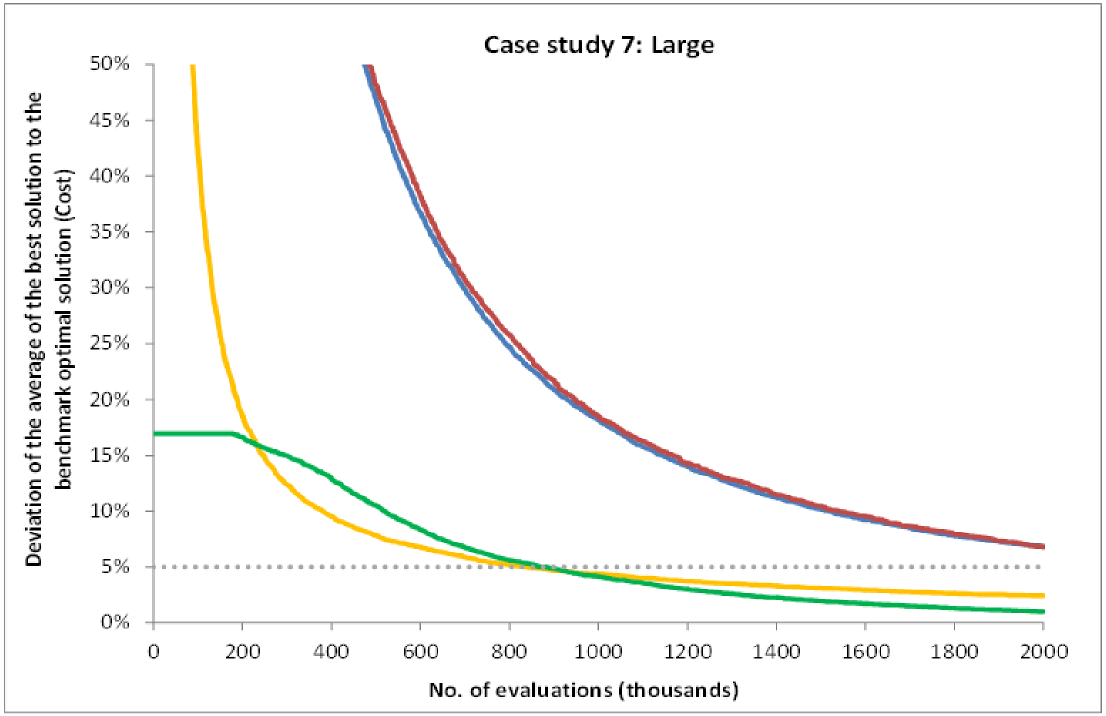
	Pipe1	Pipe2	Pipe3	Pipe4	Pipe5	Pipe6	Pipe7	Pipe8
Base Diameter (mm)	30	10	20	20	10	10	10	10
Probability Density								

(X axes: Available diameters (mm), Y axes: Probability density)

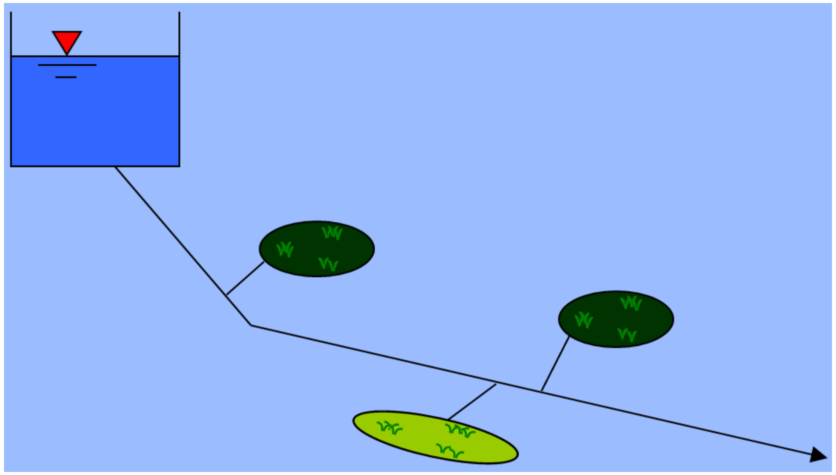
Generate initial population

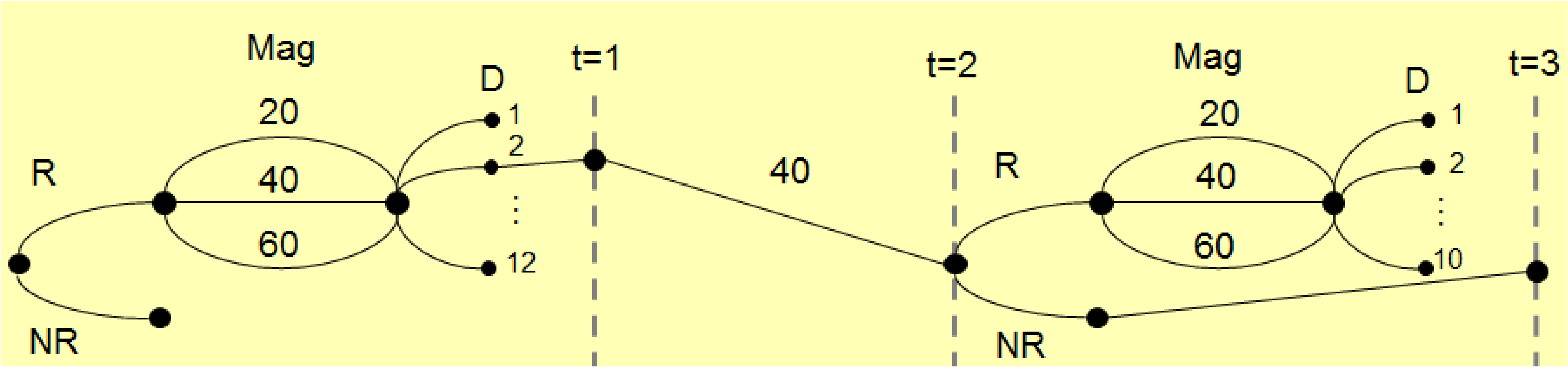
Seeding Initial Population





Dynamic Adjustment of Decision Space





Incorporation of Heuristic Knowledge